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TUBULAR LUMINESCENCE LAMPS

by P. SCHOUWSTRA and G. ZECHER.

By the application of luminescent substances a satisfactorily efficient light source (30 lm/W including losses) has been developed from the low-pressure mercury discharge, which by itself has a low light yield. Distinctive of this light source, whose development and properties are discussed in this article, is the linear form and the low brightness, which makes it specially suitable for decorative illumination. As an example of its use, a circuit is described in which nine lamps with a total length of 18 m are connected in series with a high-tension transformer. Lamps working on low tension will be discussed later. The lamps are made in two types, one of which gives a light which may be compared with electric light while the other more nearly approaches daylight.

The column discharge in mercury lamps at low pressure has long been used in the familiar blue tubular lamps for advertising. At the very low mercury pressure prevailing in these tubes (less than 0.01 mm) the radiation emitted consists chiefly of the ultraviolet resonance line 2 537 Å, while the spectral lines in the visible region are only relatively weakly developed. The fact that as a result of this the efficiency of the tubes is low, was of no importance in their use for advertising purposes, since it was not a question of illumination, but of the attraction formed by the striking colour and the possibility of giving the lamp any desired shape.

In a previous article it was explained [1]) how it is possible with the help of luminescent substances, such as certain silicates, tungstates and borates, to convert the ultraviolet radiation into a broad continuous band in the visible region of the spectrum. By this method the light yield of the low-pressure mercury discharge can be so much improved that a light source is obtained which is also useful for purposes of illumination. We shall describe the luminescence lamps which have been developed on these lines.

Design and construction

The luminescent substances used in these lamps are caused to fluoresce particularly by radiation in the spectral region of the above-mentioned mercury line 2 537 Å. The mercury pressure must therefore be chosen such that this line is emitted in maximum intensity, and it is found that the desired optimum mercury pressure is obtained in saturated mercury vapour at about 40° C. A possible method of realizing the desired mercury pressure would be to provide for the presence of a coldest spot in the lamp having the temperature mentioned. In the case of the column discharge, which is particularly favourable for the excitation of the resonance line, and which is naturally of a linear form, it may not immediately be assumed that the coldest spot in the lamp determines the mercury pressure. Due to the adsorption on the large internal surface of the luminescent powder, the velocity of diffusion of the mercury through the column is very low. Care must therefore be taken, by giving the lamp suitable dimensions, that not one spot only, but the entire wall of the column has the desired low temperature of 40 °C.

The improvement in efficiency compared with the older advertising tubes is by itself not yet enough to give an economical source of light: a certain minimum light flux per lamp is also necessary, so that the number of sources of light for a given total light flux may not be too great. The current and thus the power consumed are therefore increased as compared with the advertising tubes which give little light (60 lm/m).

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[1]) W. Uyterhoeven and G. Zecher, Low pressure mercury discharge with luminescent tube wall, Philips techn. Rev. **3**, 272, 1938.

In connection with the required relatively low wall temperature, the greater power makes it necessary to take measures for the satisfactory dissipation of heat by the walls, which means that the heat dissipating surface must be sufficiently large. An attempt might be made to achieve this purpose by increasing the diameter; objections from the point of view of glass technology are however soon encountered, and moreover the working voltage falls, which is undesirable in connection with the adaptation to the given mains voltage. The necessary surface area must therefore be obtained by increasing the length of the column. In this way one again arrives at the solution of making the lamps very long, although for different reasons than in the case of the advertising lamps. Such long tubular sources of light are already well-known to the interior decorator, and are often used for ornamental illumination. Since in the first instance this type of application was considered for the luminescence lamps, and since in this case a low brightness of the light source is in general desired, they were constructed to have a low brightness. This condition results in the limitation of the current (see above). The brightness obtained amounts to 0.3 c.p./sq.cm with a current of 250 mA (In the advertising tubes the current is only 50 mA).

The ordinary type of these lamps is of the shape shown in *fig. 1*. This lamp is 2 m long and 35 mm in diameter. The very finely divided fluorescent powder mixed with a binder is deposited in a very uniform continuous layer on the inner surface of the tube, so that the appearance is that of a milk glass tube. The electrodes for the current are in this case introduced into side tubes so that when several tubes are used (see below) long continuous lines can be formed.

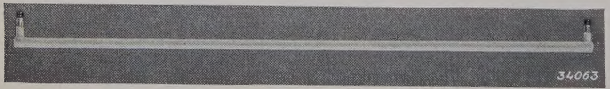

Fig. 1. The luminescence lamp type HTL 200 is 2 m long and has a diameter of 35 mm. The electrodes are in side tubes.

One of the important details in the construction of the tube is the type of cathode. In the older advertising tubes the cathode was a metal cylinder upon which a glow occurred upon discharge. Directly in front of the cathode there occurs a potential jump, the cathode drop [2]), which, due to the ion bombardment involved, may have unfavourable results on the life of the lamp, especially in the region of the so-called anomalous cathode drop. This may be avoided by limiting the current density, *i.e.* by giving the cathode a large surface, and by adding to the mercury vapour a rare gas with a pressure of about 1 cm. Both of these measures are employed in the advertising tubes, but they are not very suitable for the new source of light. The first would lead to awkwardly large dimensions of the cathode, since the current in these tubes is so much higher than in the old ones; the second has an unfavourable effect on the development of the resonance line of the mercury.

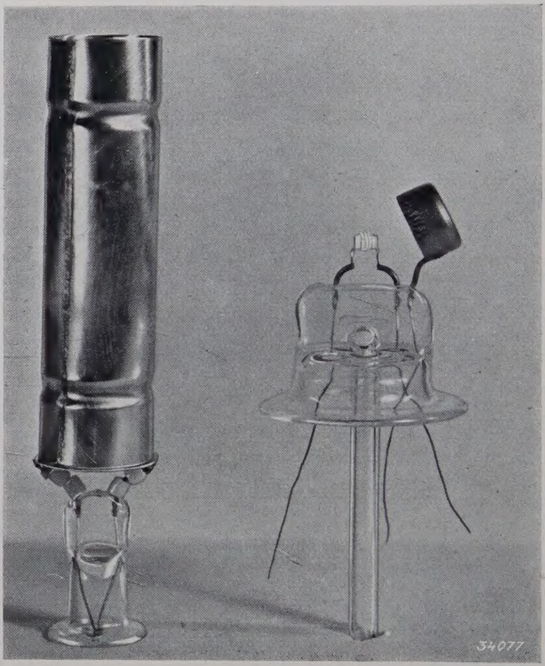

Fig. 2. Cathode of a tube for illuminated advertising signs (left) and that of the HTL 200 lamps. The cap surrounding the spiral has been bent slightly to one side in order to take the photograph.

In the luminescence lamps therefore a cathode is used in the form of a spiral covered with barium oxide, which is heated by the ion bombardment in the cathode drop and caused to emit electrons, so that the cathode drop decreases considerably. In this way the cathode may be kept small (see *fig. 2*), and the pressure of the rare gas filling can be chosen considerably lower.

Application of the lamps connected in series

Since such linear sources of light as already pointed out, are particularly suitable for illuminations where an ornamental effect is desired, the luminescence lamps are especially useful in halls, restaurants, shops, etc. Their use in such cases generally means that a number of tubes are used simultaneously, for instance to form long luminous lines (see *fig. 3*). For such installations connection of the lamps in series may be used. The low pressure mercury discharge, like all other gas discharge lamps, requires an auxiliary apparatus to limit the current when connected with the mains. If a number of lamps are connected in series only one auxiliary apparatus is needed for all the lamps. For the use mentioned therefore a high-tension transformer (leakage transformer) has been designed, the secondary of which gives a no load voltage of 6 000 volts. The middle point of the winding is earthed, so that the maximum voltage with respect to earth is 3 000 volts. Nine lamps with a total length of 18 m may be connected in series with this transformer. The ignition of these discharges requires no special measures since the necessary ignition voltage under the most unfavourable circumstances (low temperature of the surroundings) can only increase to 600 volts per lamp at the most. The working voltage is 260 volts per lamp.

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[2]) See in this connection M. J. Druyvesteyn and J. G. W. Mulder, Physical principles of gas-filled hot-cathode rectifiers, Philips techn. Rev. 2, 122, 1937.

Fewer than nine lamps can also be connected with the transformer. A number of taps on the primary have been introduced for this purpose, and the discharge current is also in this way kept within the required limits. The total consumption of an installation with 18 m of lamps and with a lamp current of 250 mA is 600 W, *i.e.* 33.5 W per meter. Since each 2 m lamp gives a light flux of 2 000 lm, the yield upon full use of the transformer is 30 lm/W. For the sake of comparision it may be recalled that the yield of an electric lamp of 2 000 lm is about 13.5 lm/W. With less than 18 m of lamps connected the efficiency is lower. For small installations and for only a single lamp some other solution is therefore to be recommended, and this problem will be discussed shortly in this periodical.

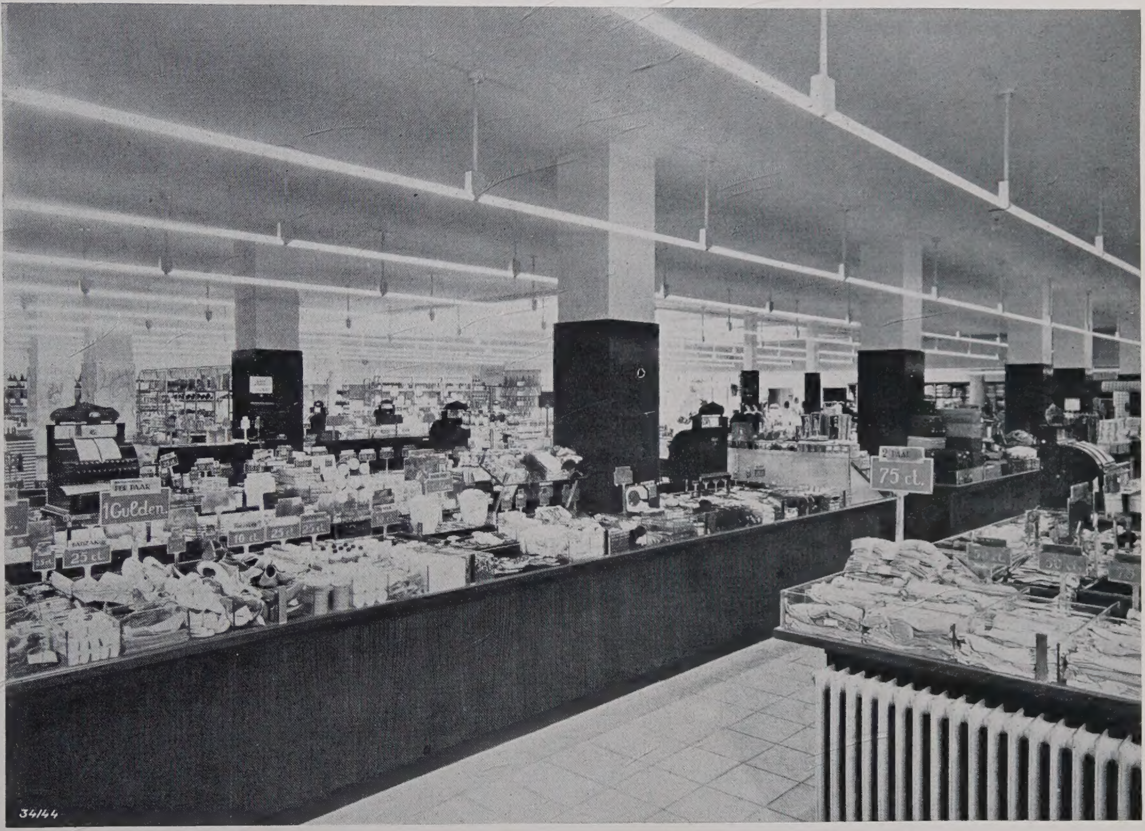

Fig. 3. Installation of a series of luminescence lamps in a shop.

Properties of the source of light

Colour of the light

The use of fluorescent substances provides not only an increase in the yield of light, but it also permits control of the colour of the light obtained. The great diversity in the emission spectra of fluorescent substances — the fluorescence light of cadmium silicates and borates for example is rose, that of zinc beryllium silicates yellow to rose, of zinc silicate green, of magnesium tungstate blue, etc., — and the possibility of depositing a mixture of the powders of these substances in any desired proportions on the inner wall of the tube make it possible to obtain a much greater variation of colours than with any other known source of light. "White" light can for instance be obtained without it being necessary to destroy some spectral part of the effective light flux by means of absorption filters. Of the numerous tints which can be realized between "cold" daylight, rich in blue, and the "warm" yellow or red of living-room lamps, two kinds of light have been chosen for the present: a yellowish white light which resembles the light of electric lamps, and a light which resembles daylight.

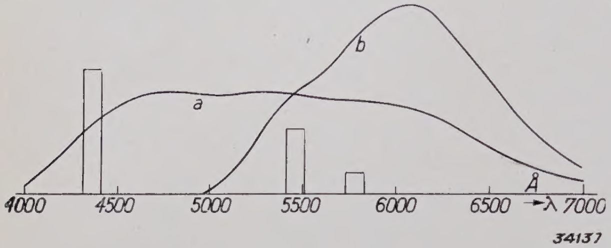

Fig. 4. Spectral distribution of energy in the two types of HTL lamps. The width of the lines of the mercury spectrum is arbitrary. Their surface indicates the energy. a) Daylight lamp. b) Yellowish white lamp.

In *fig. 4* the spectral energy distribution is shown for the two kinds of lamps. *Fig. 5* shows the light distribution curves which result from the curves of fig. 4 by the multiplication of each ordinate by the eye sensitivity corresponding to that wave length. In both figures the contribution of the fluorescence spectrum and of the mercury lines is drawn separately. (The absolute contribution of the mercury lines is about the same for both lamps.) The light of the mercury lines represents only about 10 per cent of the total light. In order to be able to judge the colour the light distribution found upon applying the block division of the spectrum, which has repeatedly been used and explained in this periodical [3]), is given in the table below.

One advantage of the luminescence lamps is the lack of any disturbing flikker. While the older advertising tubes, which have already been mentioned for comparison, are entirely extinguished and reignited in the rhythm of the alternating current used for supply, the period of the extinction of the discharge is adequately bridged over by the fluorescence of the luminescent powders in the luminescence lamps. Flikker in these lamps is hardly more noticeable than in the case of an ordinary electric lamp (see also the article cited in footnote [1])).

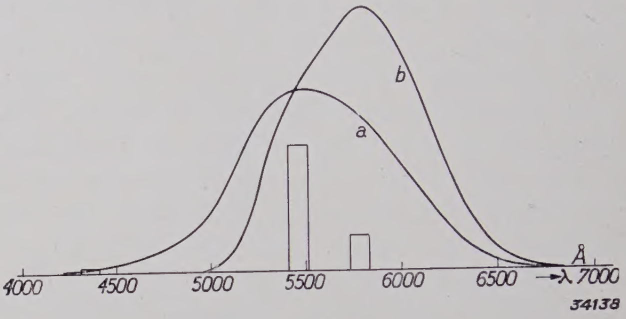

Fig. 5. Spectral distribution of the light of the two types of lamps HTL 200. a) Daylight lamp. b) Yellowish white lamp.

Sensitivity to change in working conditions

As already mentioned, for the most efficient excitation of the resonance line 2 537 Å of mercury a temperature of the glass wall of about 40 ° C is desired. If this temperature changes, the intensity of the line mentioned varies according to the curve given in *fig. 6*. It may be seen that a fluctuation of the temperature of the glass wall by 10 or 20° already causes considerable decrease in the intensity of the resonance line, and consequently in the light yield. The lamp has been so constructed that with a temperature of the surroundings of 20 °C the glass wall assumes a temperature of 40 °C. Upon a change in the temperature of the surroundings however,

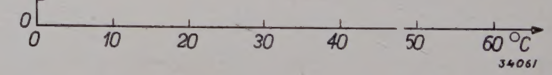

Fig. 6. Emission of the mercury line 2 537 Å in the HTL 200 lamp as a function of the temperature of the glass wall. For these measurements the lamp was placed in a thermostat; the emission was observed through an opening in the luminescent layer. The optimum emission (assumed to be equal to 100 per cent) occurs at about 40 °C.

Block (boundaries in Å)	4 000	1	4 200	2	4 400	3	4 600	4	5 100	5	5 600	6	6 100	7	6 600	8	7 200
Daylight		0.025		0.26		0.91		11.1		40.8		36.2		9.9		0.73	
HTL daylight		0.015		0.30		0.65		9.4		4.70		33.0		7.6		2.03	
Electric lamp		0.005		0.058		0.25		5.4		33.5		42.7		16.6		1.54	
HTL yellowish white		0.003		0.15		0.05		0.46		33.0		50.6		15.2		0.58	

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[3]) On the method of measurement and application see P. M. van Alphen, A photometer for the investigation of the colour rendering reproduction of various light sources, Philips techn. Rev. 4, 66, 1939.

the temperature of the glass wall varies to a much smaller degree, as shown in *fig. 7*. In this figure the light delivered by the lamp is plotted as a function of the temperature of the surroundings. When the latter has fallen to 5 °C the light yield is still 80 per cent of its normal value. The curve is valid for the case where the heat dissipation takes place only by radiation and conduction. If convection is also active, due for instance to the lamp being exposed to the wind, the temperature of the glass wall then follows the fluctuations of the temperature of the surroundings much more closely, and the light flux may fall sharply. This is the reason why luminescence lamps are intended chiefly for indoor use alone.

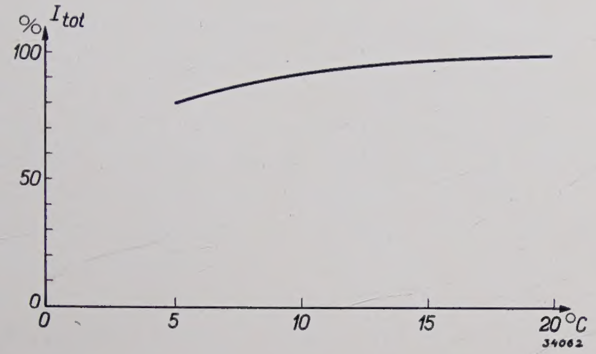

Fig. 7. Light intensity of HTL 200 as a function of the temperature of the surroundings recorded indoors. The temperature of the glass wall varies much less than that of the surroundings as long as no heat is dissipated by convection.

Immediately after ignition the mercury pressure is lower than the optimum value. From fig. 6 it may be deduced that at this moment, with a wall temperature of about 18 °C, the light flux is about 60 per cent of the maximum value. After $^1/_2$ minute it has already reached 90 per cent, while the final value is reached in about 3 minutes.

One important advantage of the luminescence lamps compared to the ordinary electric lamp is its slight sensitivity to fluctuations in the mains voltage. *Fig. 8* shows the variation of the different properties with the mains voltage. With increased mains voltage the lamp current rises, the working voltage however falls, so that the power consumed increases only relatively little. The yield is practically constant in the normal range, so that the light flux also varies only slightly: increase or decrease of the mains voltage by 10 per cent causes an increase or decrease, respectively, of the light flux also by 10 per cent. In the case of the ordinary electric lamp the corresponding fluctuations of the light flux would be about 40 per cent.

Such fluctuations in the voltage have no effect on the life of the lamps, contrary to the case of ordinary electric lamps. The life of the lamp is limited only by the two following phenomena. In the first place the emitting layer of the cathode is consumed. Repeated switching on and off has a particularly unfavourable effect in this respect. As fas as the electrodes are concerned a life of 2 000 hours may be counted on with a normal amount of switching on and off. During this time however a certain decrease in the light flux takes place due to blackening similar to that observed in electric lamps. In the luminescence lamps this blackening is due to the deposition of mercury ions from the discharge on the fluorescent layer which covers the inner wall of the tube. The mercury deposit absorbs part of the ultraviolet radiation which excites the fluorescence and thus causes a loss of light. The process of blackening which takes place more rapidly at the beginning, and which is therefore largely completed after the customary testing of the lamps, depends upon the nature of the fluorescent powder. In the case of the lamps for daylight colour blackening is lowest.

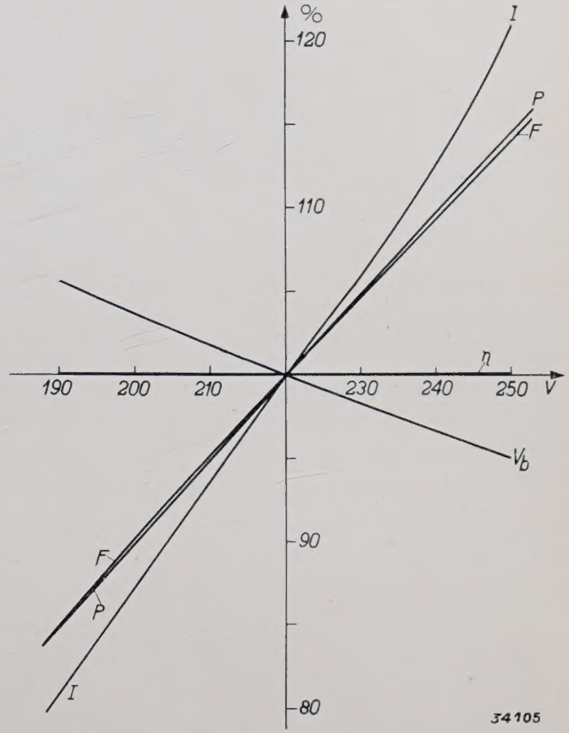

Fig. 8. Relative change of lamp current I, working voltage V_b, power consumed P, efficiency η and light flux F as a function of the mains voltage (normal 220 volts).

TELEVISION RECEIVERS

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The previously described television receiver has been improved and simplified by the use of components of a new type, among which are amplifier valves with secondary emission, relay valves and cathode ray tubes with magnetic deflection. The most important details of the new type of receiver are here described.

About two years ago a television receiver was described in this periodical [1]) which was designed for reception of the programmes transmitted by the B.B.C. in London. The development of this apparatus has been continued, and it has been found possible to simplify the circuit considerably by the use of components of an improved type, and to make the apparatus suitable for series manufacture.

The new television receivers which will be described in the following are tuned to the London transmitter (carrier wave of the picture 45 megacycles, carrier wave of the sound 41.5 megacycles) or to the Paris transmitter (carrier wave of picture 46 megacycles, of sound 42 megacycles). Both of these transmitters use interlaced scanning. The picture transmitted by the London station has 405 lines, that of the Paris transmitter 455 lines.

The television signal

The television receiver must amplify and rectify the incoming signal, and break it up into four parts: the picture signal, the sound signal, the picture synchronization signal and the line synchronization signal. The picture signal is fed to the control electrode of a cathode ray tube, the sound signal goes to a loud speaker, the synchronization signals serve to synchronize two saw tooth wave generators which provide the currents necessary for the horizontal and vertical deflection of the electron beam to scan the whole surface of the screen.

We shall first examine the way in which the different signals are dealt with in the modulation of the television transmitter. We need only consider the picture voltage, since the sound is modulated in the ordinary way on a separate carrier.

In *fig. 1* the modulation is given of the picture signal of the London transmitter. The ordinate

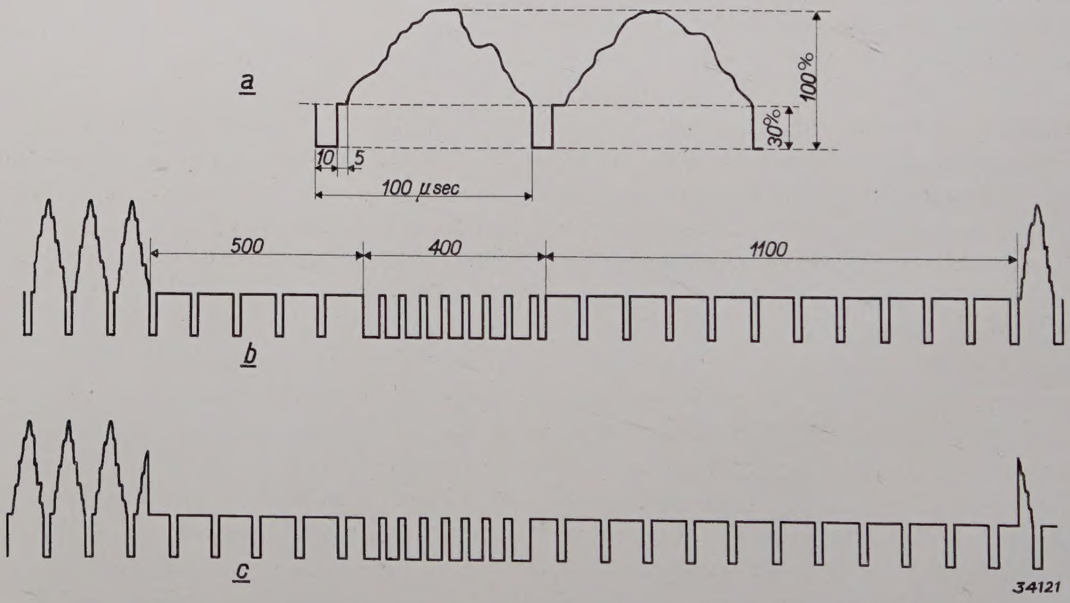

Fig. 1. Modulation of the television signal. The range of brightnesses from black to white is reproduced by a change of the amplitude between 30 and 100 percent. In *a* may be seen the line synchronization signal which consists of a total suppression of the signal during 10 micro seconds and a "black" signal of 5 μ sec. In diagrams *b* and *c* the even and odd picture synchronization signals, respectively, are given. The duration of these signals is 400 μ sec, while the picture modulation is suppressed throughout an interval of 2 000 μ sec each time. The picture synchronization signal is interrupted by a number of impulses which provide the line synchronization. As may be seen there are twice as many impulses during the picture synchronization signal as is necessary for line synchronization. In this way the odd and the even signals are made to appear practically the same, which is desirable since otherwise there is danger that the two line patterns of the interlaced image may be mutually displaced.

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[1]) Philips techn. Rev. 2, 33, 1937.

gives the amplitude of carrier in per cent of the maximum amplitude. At moments when the screen is dark the carrier has an amplitude of 30 per cent. With increasing brightness the amplitude increases to 100 per cent. At the end of each line of the picture the amplitude of the carrier falls to zero for an instant (line synchronization). This takes place $405 \cdot 25 \sim 100\,000$ times per second. In addition, picture synchronization takes place 50 times per second and a distinction must be made between odd and even picture synchronization, in connection with the interlacing (see *fig. 2*). An even picture synchronization is shown in fig. 1*b*, an odd one in fig. 1*c*. Both of these consist mainly of an interruption of the carrier like the line synchronization signal, but they are in this case of longer duration, namely long enough for four lines to be scanned. For further details refer to the text under fig. 1.

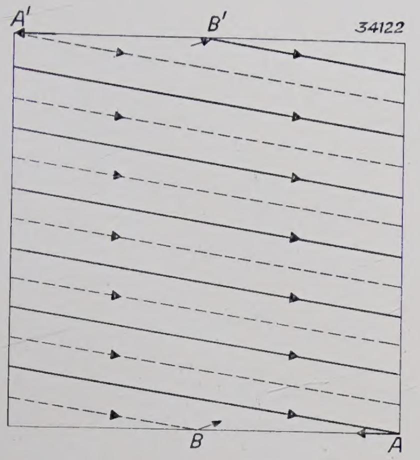

Fig. 2. Synchronized scanning. The "even" picture synchronization signal begins at the end of a line, the "odd" one begins in the middle of a line.

Circuit arrangements of the receiver

In *fig. 3* a very much simplified diagram is given of the circuit of the television receiver. Each valve is indicated by a circle, while the other elements of the circuit are emitted. Picture and sound signals are picked up by the aerial *A* and amplified together in the first amplifying stage. The signals are then sent to the mixing stage consisting of two triode-hexodes.

The signals on the intermediate frequency carrier are separated into sound signals, with a frequency of about 9.7 megacycles, and the band of picture and synchronization signals, which extends from 10.4 to 13.2 megacycles.

The sound signals are amplified and rectified on the intermediate frequency carrier, amplified on a low-frequency carrier and fed to the loud speaker *L*.

The picture and synchronization signals are amplified by a broad band amplifier in two stages (Sp_1, Sp_2). They are rectified by means of the diode D_b and then immediately passed to the control electrode *g* of the cathode ray tube. The synchronization signals are separated by means of the stage P_s D_s from the picture signals, and are then sent to the saw tooth generators for line and picture, each of which consists of two stages. The output signals from these supply the coils Sp_1 and Sp_2 for horizontal and vertical deflection, respectively.

If the circuit is compared with the one given two years ago for the television receiver, the most striking difference is the great decrease in the number of valves. The intermediate frequency picture signals which were previously amplified in three stages are now amplified in two stages. The intermediate frequency sound signals are now amplified

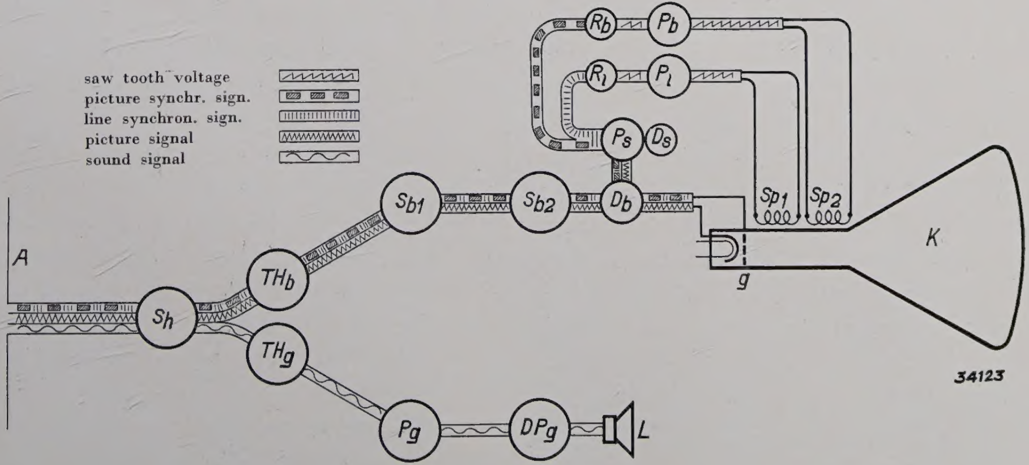

Fig. 3. Amplification of the television signal und gradual separation into sound, picture, line synchronization and picture synchronization signal. *S* amplifier valves with secondary emission, *TH* triode-hexodes, *P* pentodes, *D* diodes, *R* relay valves, *Sp* coils, *K* cathode ray tube, *L* loud speaker.

by only one stage, while previously two stages were needed. In the amplification of the synchronization signals also, as well as in the construction of the saw tooth generators, the number of valves has been decreased.

This saving has been made possible in the first place by the use of amplifier valves with secondary emission. These valves have a slope of 13 mA/Volt, a value which is not so easily reached without secondary emission ²). A further saving in valves was achieved by using relay valves in the saw tooth generators, while finally the circuit which separates the synchronization signals from the picture signals requires fewer valves than the one designed two years ago.

In the following we shall examine a few important details of the circuit.

The mixing stage

The mixing stage serves the purpose of transferring the modulation of the sound and the picture to a new carrier wave. It is desirable to separate picture and sound from each other at the same time. In the circuit for the sound selective resonance circuits can then be applied so that a much higher amplification factor can be reached than in the amplification of the broad frequency band which the picture signals occupy.

Fig. 4 shows how this separation is brought about. The input circuit, consisting of the coils L_1, L_2 and the condenser *C*, forms a bandfilter whose elements are so chosen that only the broad frequency band of the picture signals are passed to the triode-hexode TH_b, while the sound signals are very much weakened. This filter is followed by the blocking circuit *lc* which is adjusted to the carrier of the sound signal and thus suppresses this carrier even more. The coils L_1', L_2' and the condenser *C'* form a second band filter tuned to the narrow frequency band of the sound signal, which passes this signal to the grid of the second triode-hexode TH_g.

The oscillator parts of the two triode-hexodes are brought into oscillation by means of the same oscillating circuit. The connections are shown in the figure, and it may be seen that the voltages on the oscillator grids vary in opposite phase.

The anode circuits of the hexode parts, in which the mixing frequency is generated, are different for picture and sound. The picture signal, which occupies a broad frequency band, is transmitted to the following stage by means of a transformer. The sound signal is amplified selectively by means of a tuning circuit which, together with the circuit coupled with it, forms a filter passing a band 40 kilocycles in width.

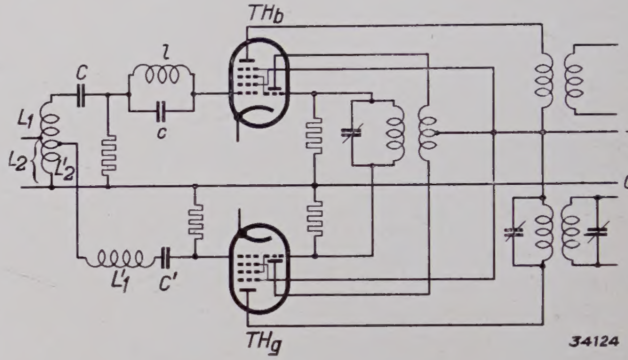

Fig. 4. Circuit of the mixing stage. The elements L_1, L_2, *C*, *l*, *c*, L_1' and *C'* serve to separate the sound signals which are passed on to the grid of the triode-hexode TH_g from the picture signals which are passed on to the grid of the triode-hexode TH_b.

The intermediate frequency amplification

In general it may be said that it is more difficult to obtain good amplification with a single valve, the greater the frequency range to be amplified. In an earlier article in this periodical ³), in which the amplifier of a cathode ray oscillograph was described, parasitic capacities (mainly the input and output capacities of radio valves) were indicated as causes of the difficulties which occur in the amplification of a broad frequency band. In the same article a discussion was given of the method of choosing coupling elements between two valves in order to obtain the highest possible amplification which is constant for frequencies from about 10 cycles to 1 megacycle.

We are here concerned with a slightly different case: the amplification must also be constant over a broad frequency band which, however, lies between two high frequencies of about 11 and 13 megacycles. We can however profit by the results there found by making use of the following proposition.

Given, a network consisting of capacities C_1, self-inductions L_1 and resistances R_1. If in this network we connect a self-induction L_2 in parallel with every capacity C_1 and a capacity C_2 in series with every self-induction L_1, choosing the quan-

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²) On the subject of valves with secondary emission see Philips techn. Rev. **3**, 133, 1938. The application of secondary emission offers as principal advantage the possibility of obtaining a given anode current with a smaller cathode than when the current must be generated entirely by thermionic emission. By the reduction of the dimensions the input capacity is also lowered, which is a great advantage in the amplification of broad frequency bands.

³) Philips techn. Rev. **4**, 198, 1939.

tities L_2 and C_2 such that the sections are tuned to a frequency ν_0 in the following way:

$$C_1 L_2 = L_1 C_2 = \left(\frac{1}{2\pi\nu_0}\right)^2,$$

Then the newly formed network, at the frequencies,

$$\left.\begin{aligned} \nu_1' &= \sqrt{\nu_0^2 + \frac{\nu^2}{4}} + {}^1/_2\,\nu \\ \nu_2' &= \sqrt{\nu_0^2 + \frac{\nu^2}{4}} - {}^1/_2\,\nu \end{aligned}\right\} \quad . \; . \; . \quad (1)$$

has the same absolute values of the impedances as the original network at the frequency ν.

In order to prove this it is sufficient to calculate the impedance of a section which in the original network contains only a self-induction or a capacity (the resistances remain unaltered). The self-induction is changed to a self-induction and a capacity in series, tuned to ν_0. Then at a frequency ν, one finds for the absolute value of the impedance

$$|Z| = 2\pi\left|\left(\nu' - \frac{\nu_0^2}{\nu'}\right)\right| L$$

and when ν' is substituted in this equation according to equation (1), one obtains

$$|Z| = 2\pi\nu L,$$

or the same value as in the original network at the frequency ν. A similar calculation can also be carried out for the capacitive sections of the original network; it is better in this case to calculate the admittance instead of the impedance.

When the original network has a frequency characteristic, which is flat up to a maximum frequency ν, the frequency characteristic of the new network will be flat between two frequencies ν_1 and ν_2', which have the following relation according to equation (1)

$$\nu_1' - \nu_2' = \nu.$$

The extent of the flat frequency region remains thus unaltered, the region is merely shifted to higher frequencies.

On the basis of *fig. 5* we shall explain the coupling of two successive amplifier valves in the broad band amplifier with the help of this proposition. Fig. 5*a* is in principle a resistance-coupled amplifier having a flat characteristic in a frequency range which begins at very low frequencies, and whose upper limit is given by the electrode capacities of the radio valves which short circuit the resistance R for very high frequencies. The self-induction L prevents to some extent the decrease in the amplification with increasing frequency, by increasing the anode impedance with increasing frequency.

Fig. 5*b* is a diagram of an equivalent circuit for the coupling elements of the resistance amplifier. Fig. 5*c* is the equivalent circuit deduced therefrom of the broad band amplifier in which C_1 and M are self-inductions. Fig. 5*d* is the arrangement corresponding to this equivalent circuit.

There are two points of difference between the circuit and its equivalent, which, however, do not destroy their electrical equivalence. In the first place the self-induction M is replaced by the mutual induction between the coils of a transformer; in the second place the circuit L, R, C_1 is not connected in parallel with the entire secondary winding of the transformer, but only with a part of it. This is done because otherwise the capacity C_1 should have an impractically small value. In the case shown this capacity is 4 $\mu\mu$F.

The anode impedance of the whole circuit has the fairly low value of 4 000 ohms, with which an amplification per stage of 50 times is obtained, thanks to the steep slope of the valves. The amplification is constant in a frequency range of two megacycles.

The rectification of picture and synchronization signals

The picture signals are rectified in the ordinary way with a diode as shown schematically in *fig. 6a.*

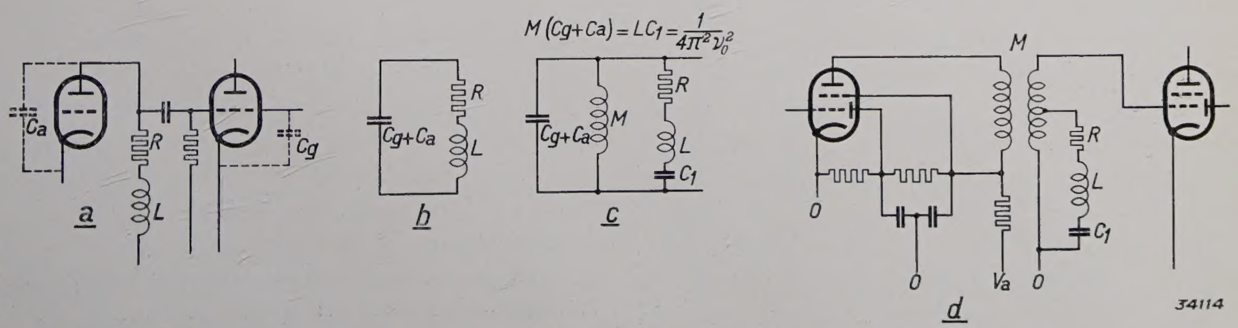

Fig. 5. *a* Diagram of a resistance-coupled amplifier, the amplification of which for high frequencies is raised by the self-induction L. *b* Equivalent circuit of the resistance amplifier, *c* equivalent circuit of a broad band amplifier derived from *b*, *d* circuit of the broad band amplifier.

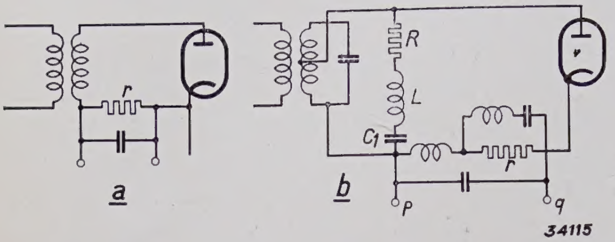

Fig. 6. *a* Principle, *b* circuit of the diode for rectifying the video frequency signals. By means of several elements in series, connected in parallel with the resistance *r*, an effort is made to render the impedance between the points *p* and *q* as constant as possible for the video frequencies occurring. The circuit element *R*, *L*, C_1 have the same significance as in fig. 5.

The "video frequency voltage" obtained, which fluctuates in the rhythm of the amplitude of the picture signal, is passed directly to the control electrode of the cathode ray tube. In fig. 6*b* may be seen the actual circuit which is explained in the text beneath the figure.

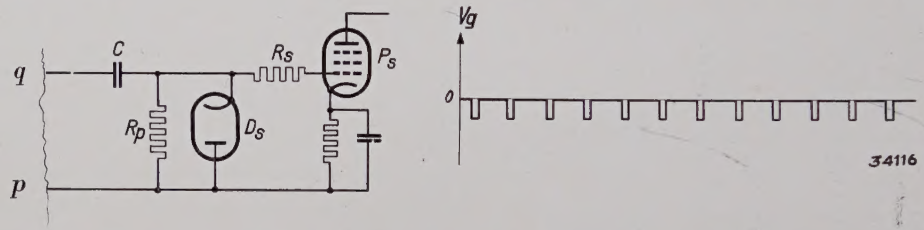

Fig. 7. Amplification of the synchronization signals and their separation from the picture signals. *a* Principle of the amplifier stage which is connected with the rectifier stage of fig. 6*b*. By connecting a diode D_s in parallel with the resistance R_p the bias of the control grid is kept at such a value that its total voltage with respect to the anode of the diode D_s is exactly zero at the lowest point of the synchronization signals, and otherwise positive. The diagrams beside the circuits *a* and *b* show the corresponding variation of the grid voltages with respect to the cathode of the pentode.

The synchronization signals which are also present in the rectified voltage are not yet sufficiently strong to be able to drive the saw tooth generators. They are therefore amplified once more and at the same time separated from each other. This is represented schematically in *fig.* 7. The rectified picture- and synchronization signals are sent to the grid of the pentode P_s *via* a coupling condenser *C*. The resistance R_s and the diode D_s need not to be considered. The control grid of the penthode P_s has a negative grid bias, wich is obtained by inserting a resistance in the cathode circuit.

Now we can first consider the case, that the plane of the image is dark and that between *p* and *q* only a synchronisation signal exists, which equals the just mentioned negative grid bias. Between two synchronisation signals, however, the grid bias equals zero and at every signal a sharp peak occurs, as indicated in fig. 7.

If a picture signal exists, together with the synchronisation signal, we want quite the same behaviour of the grid bias. This is obtained by means of the resistance R_s. The picture signal gives a positive voltage to the control grid and a grid current flows. This means that the resistance between cathode and control grid becomes small with respect to the resistance R_s, so that only a small part of the voltage remains between *p* and *q* on the control grid. This grid current would cause the originally chosen grid bias of the penthode P_s to disappear. Every time the grid bias is becoming positive, a current starts which charges condenser *C* negatively and continually lowers the mean grid bias. In order to eliminate this difficulty a diode D_s is put in parallel with the resistance R_p which at once conducts away the charge of the right condenserplate, if the potential of this plate becomes negative with respect to the anode of the diode. In this manner the influence of the picture signal on the grid bias is completely eliminated.

The saw tooth generators

The saw tooth voltage is excited by means of a so-called relay valve, that is a gas-filled triode in which a gas discharge takes place at a certain anode voltage which depends upon the voltage on the grid [4]).

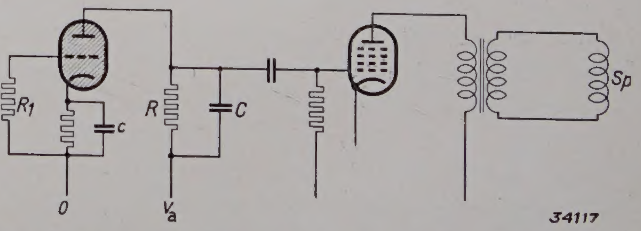

Fig. 8. Diagram showing the principle of a generator causing a saw tooth current through the deflection coil *Sp*. By means of a relay valve a relaxation oscillation is generated. A saw tooth voltage hereby occurs over the condenser *C*, which is amplified with the help of a pentode.

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[4]) On the action of relay valves see Philips techn. Rev. **1**, 11, 1936.

The circuit of the saw tooth generator is represented in *fig. 8.* When the voltage V_a (about 300 volts) is applied, the condenser C is charged. The charge flows off gradually over the resistance R, so that the voltage of the anode increases proportionally to the time. At a voltage of several tenths of a volt the relay valve breaks down; the charge of the condenser then flows *via* the relay valve to the condenser F, so that the anode voltage falls very rapidly and at the same time the cathode voltage suddenly rises. The potential difference between cathode and anode quickly becomes zero; at that instant the discharge is extinguished, and the process begins again.

The saw tooth voltage on the condenser C so obtained is amplified by means of a pentode, which provides a saw tooth current which is fed to one of the deflection coils of the cathode ray tube.

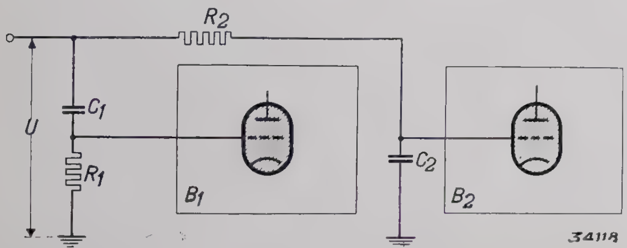

Fig. 9. Synchronization of the saw tooth generators B_1 and B_2 which generate the line and picture saw tooth voltages, respectively. The synchronization is carried out by means of voltage impulses on the control grids of the relay valves. These voltages are derived from the voltage U (output voltage of the pentode P_s in fig. 7) by means of the circuits C_1R_1 and R_2C_2, respectively.

The synchronization of the saw tooth voltage is obtained by increasing the grid voltage of the relay valve suddenly at certain moments and in this way initiating a breakdown. This takes place in the rhythm of the synchronization signals, and provision must be made, by the use of suitable switching elements, that the one saw tooth generator is synchronized by the line synchronization signals and the other by the picture synchronization signals.

The possibility of separating line and picture synchronization signals is based upon the fact that the duration of the latter is 40 times that of the former (see fig. 1). If a condenser and a resistance are connected in series, a voltage which is suddenly applied to this circuit and then immediately withdrawn, will only act on the resistance. If however the voltage remains constant for some time, the condenser becomes charged over the resistance, so that finally the whole voltage acts on the condenser.

In *fig. 9* it may be seen how the saw tooth generators B_1 and B_2 for the horizontal and vertical deflection, respectively, of the electron beam, are activated by means of the voltage U. The horizontal deflection is synchronized by the voltage peaks which the line synchronization signals excite on the resistance R_1; the vertical deflection is synchronized by the voltage caused by the picture synchronization signals on the condenser C_2.

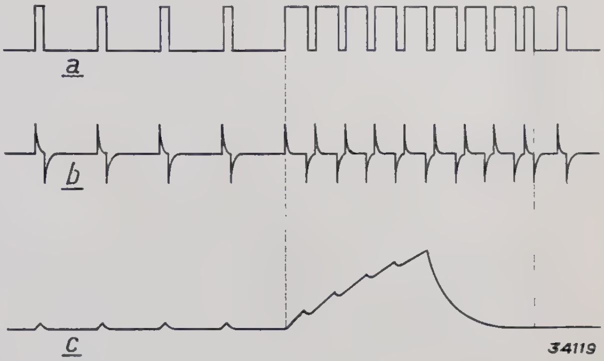

Fig. 10. Variation *a*) of the output voltage U, *b*) of the grid voltage of the valve B, *c*) of the grid voltage of the valve B_2. At each line synchronization signal *b* exhibits a voltage peak which ignites the valve B_1. During the picture synchronization signal the number of peaks is twice as great; only every other peak, however, initiates a breakdown. (At each breakdown the condenser *c* in fig. 8 is charged, so that the voltage of the cathode becomes positive with respect to the grid. At the following peak this voltage has not yet fallen back so far that the valve can break down). Curve *c* exhibits only unimportant voltage peaks at the line synchronization signals; the picture synchronization signal however gives such an increase in voltage that the valve breaks down.

The variation of the voltages is indicated by curves *a*, *b* and *c* of *fig. 10*. Curve *a* represents the variation of the synchronization signal proper, *i.e.* the anode voltage of the pentode P_s in fig. 7. Curve *b* gives the variation of the voltage on the grid of the relay valve B_1, which is coupled with the output voltage of the pentode P_s by means of the elements C_1 and R_1. It is clear that a sufficiently sudden change of voltage, like the front of the line

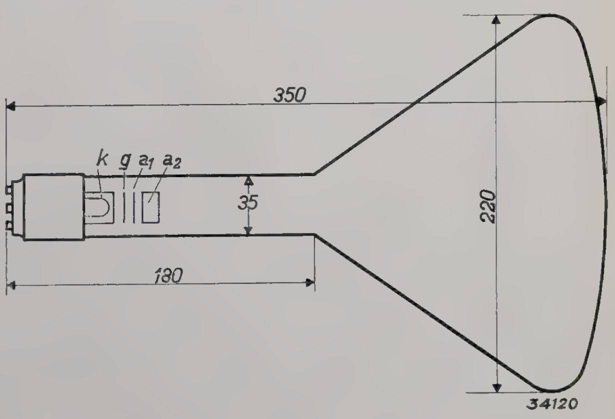

Fig. 11. Cathode ray tube with magnetic deflection of the electron beam. *k* cathode, *g* control electrode, a_1, a_2 anodes. Dimensions in mm.

synchronization signal, is passed on practically unweakened by the condenser C_1 to the grid of the relay valve. The *R-C* time of the circuit C_1-R_1 is however so short that the voltage falls again practically to zero within the duration of the synchronization signal; the end of the synchronization signal then causes a peak in the opposite direction (fig. 10*b*). The positive peaks cause breakdown in the relay valve, the negative peaks are without significance. It may be seen how the synchronization of the line saw tooth generator is also maintained during the picture synchronization signal (which lasts for four line periods); further particulars are given in the text under the figure.

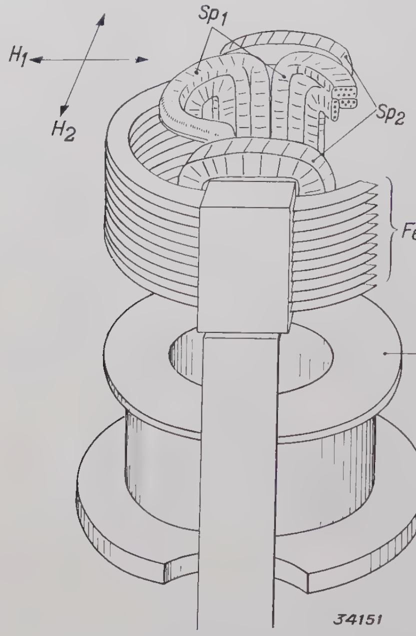

Fig. 12. Coils for focussing and deflection of the electron beam. *F* focussing coil, Sp_1 deflection coil for the line saw tooth voltage (direction of the magnetic field H_1), Sp_2 deflection coil for the picture saw tooth voltage (direction of field H_2). *Fe* series of iron rings for reinforcing the field H_2.

Curve *c* shows the variation of the voltage on the grid of the valve B_2, which is controlled by the picture synchronization signals. The circuit R_2C_2, through which this valve is coupled with the synchronization signals, is connected in a way opposite to that of the circuit C_1R_1, so that the voltage of the condenser instead of that of the resistance acts on the grid, and this voltage only increases sufficiently to cause breakdown in the relay valve at a given moment after the longer duration of the picture synchronization signals.

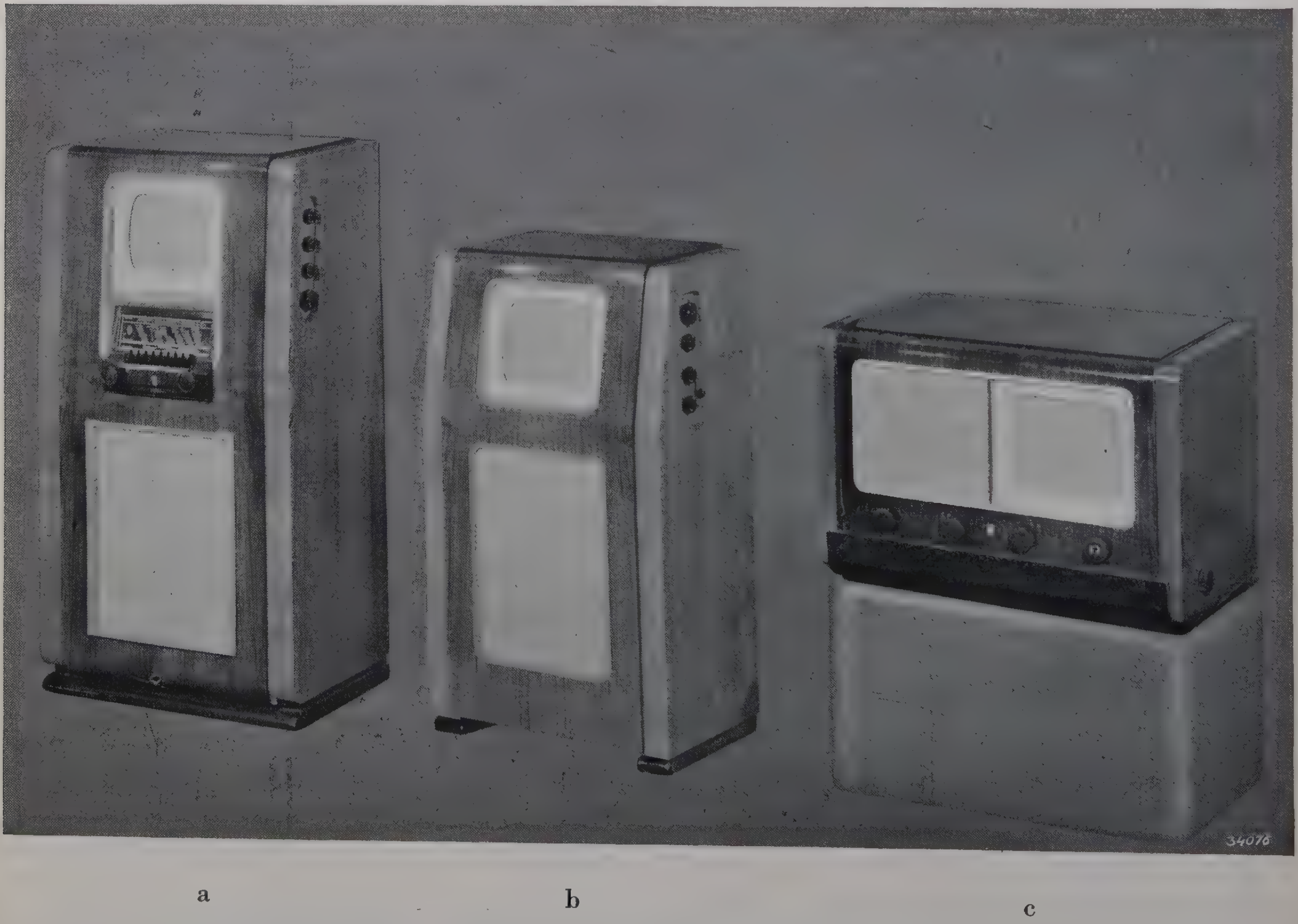

Fig. 13. Various television receivers. *a* Console model with built-in radio receivers; *b* console model for television alone; *c* table model.

The cathode ray tube

After having discussed in the foregoing the formation of the picture voltages and the saw tooth currents, we shall now study how a picture is formed on the screen of the cathode ray tube (*fig. 11*) by means of these voltages and currents. The electrons which leave the cathode are accelerated by the anodes a_1 and a_2. The control electrode g receives the picture voltages and regulates the intensity of the electron beam and thus the brightness of the fluorescence spot moving across the screen. Furthermore the electron beam must be focussed and deflected in two perpendicular directions proportionally to the currents from the saw tooth generators. This is done magnetically by a system of coils shown in *fig. 12*. The coil F causes a field in the direction of the axis of the tube. This field is adjusted to a constant intensity and serves to focus the electron beam.

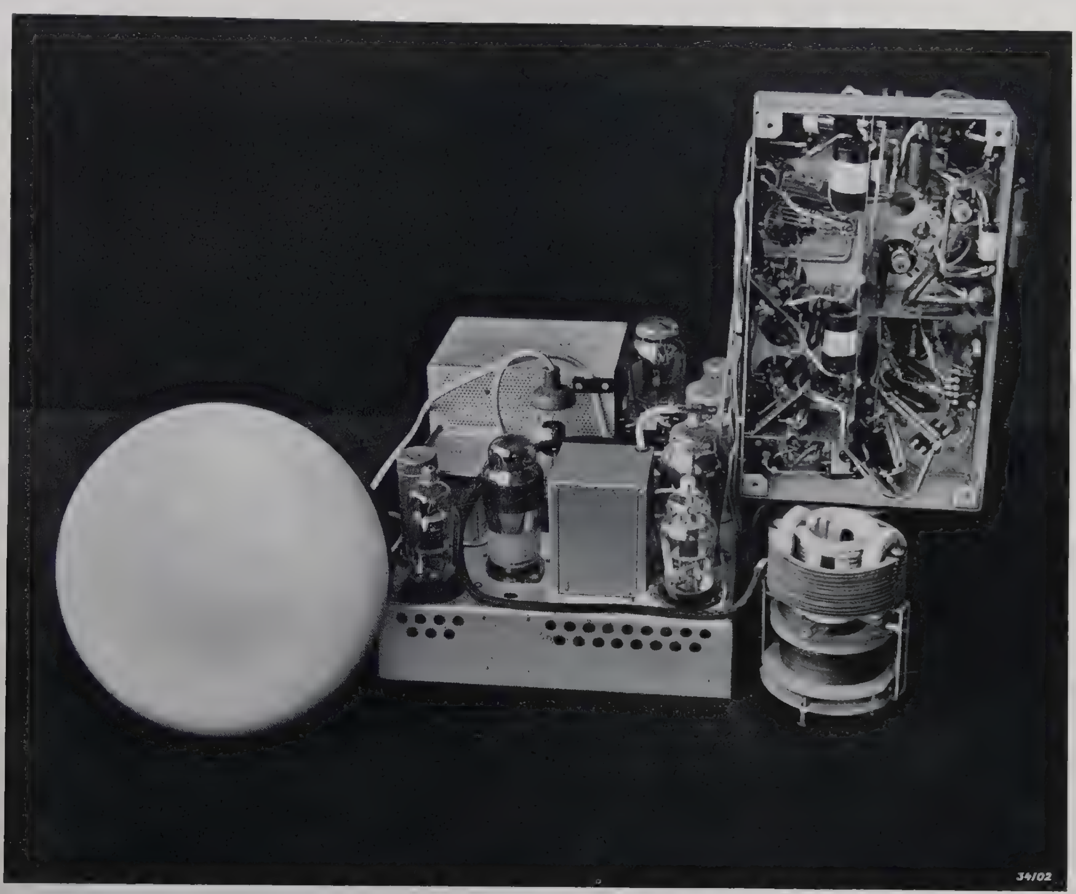

Fig. 14. The two chassis of a television receiver (console model). To the left may be seen the screen of the cathode ray tube, next to it a chassis with the power pack and the saw tooth generators and next to that — mounted in a vertical plane — a chassis with the amplifier stages for picture and sound signals. Below this chassis there is a system of coils for the focussing and deflection of the electron beam.

The coils S_{p1} and S_{p2} cause magnetic fields which are mutually perpendicular and also perpendicular to the axis of the tube. The coil S_{p1} deflects the electron beam in the direction of the lines scanned. This coil, which causes a magnetic field in the direction of the arrow H_1, has a somewhat distorted form due to the fact that two originally flat coils were bent as closely as possible around the neck of the cathode ray tube. This has been done in order to make the field inside the neck as strong as possible by shortening the lines of force. It is desirable to keep the length of the cathode ray tube small, since this determines the dimensions of the apparatus, and to make the area of the screen as large as possible. As may be seen from the figure the diameter of the screen is almost two thirds of the total length of the cathode ray tube. In the tube represented the picture on the screen is 17.5 cm wide and 15 cm high. Television receivers are also made with a somewhat larger cathode ray tube giving a picture 25 cm wide and 20 cm high. The attainment of such large screens with relatively short cathode ray tubes has only been made possible by changing over from electrostatic to magnetic deflection, and this advance has contributed very much to the decrease in the size of television receivers.

The complete apparatus

The parts are assembled in two chassis, one of which contains the power pack and the saw tooth generators and the other the amplifying stages for picture, sound and synchronization signals. As to the position of the two chassis in the apparatus, there are various types. In the table model, shown in *fig. 13c*, the two chassis are side by side. The loud speaker is mounted above the power pack, the cathode ray tube above the amplifier. In the different cabinet models the amplifier chassis is assembled in a vertical plane (*fig. 14*). The two chassis are at the bottom of the cabinet, above the power pack is the loud speaker and at the top the cathode ray tube. The result is a cabinet 80 cm high, which is shown in fig. 13*b* next to the table model. In addition to these two models there are a number of larger models (fig. 13*a*, for example) in which, in addition to a television transmitter, any desired broadcasting station can be received.

Compiled by G. HELLER.

THE DRY SHAVING APPARATUS "PHILISHAVE"

by A. HOROWITZ, A. van DAM and W. H. van der MEI.

672:715 : 621.312

Dry shaving with an electrical shaving apparatus offers the advantage over shaving with soap and razor that the skin is less damaged and cuts are impossible. In this article the action and construction of the dry shaving apparatus "PhiliShave" developed by Philips are discussed.

Introduction

Dry shavers are so called because the hairs of the beard are cut off mechanically without any previous treatment with soap or cream. Although the idea is an old one (one such apparatus was proposed in the previous century), it has only recently been possible to find a satisfactory method of construction.

In designing a dry shaver the obvious starting point was the hair clipper used by hair dressers. The cutting element of this apparatus consists of two steel combs with perfectly plane surfaces lying together (see *fig. 1*). The upper comb is moved back and forth over the lower one and the hairs are caught and cut off between the teeth of the two combs as they slide over each other.

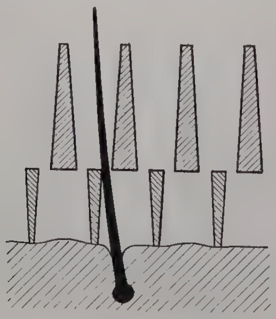

Fig. 1. Sketch showing the principle of a hair clipper. The hairs are cut off by means of two combs sliding over each other.

If this principle is applied in the correct way to the problem of shaving the beard, then in addition to the convenience of dry shaving, is the advantage that the skin is much less damaged. In connection with this latter point it is important to know something about hair growth. The hairs grow from pores. These pores may in general be of two types. In one case the pore is a craterlike depression surrounded by fairly smooth skin, while in the other case there is a tiny elevation of the skin at one side of each hair (see *fig. 2*). Both forms occur simultaneously in most cases. In shaving with a razor the cutting edge passes directly over the skin and these tiny elevations are partially cut off with the result that numerous tiny wounds

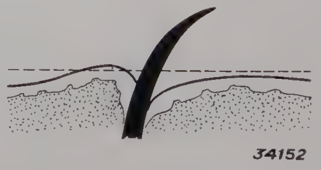

Fig. 2. The skin on one side of a hair often forms an elevation, as shown in the figure. The dotted line shows how the skin is damaged when such a hair is cut by an ordinary razor.

are made. With a dry shaver the lower comb can be so constructed that it runs smoothly over the inequalities of the skin. When slight pressure is exerted on the apparatus the elevations are pushed flat so that the hairs can be cut very short without harm to the skin. It is obvious that pimples etc. give rise to further small wounds in shaving with a razor, and that this again may be avoided by the use of an instrument on the principle of the hair clipper.

Before entering into the details of the dry shaver developed by Philips, the action of which exhibits certain analogy with that of a hair clipper, we shall first consider the factors which effect the action of a hair clipper.

Requirements which must be satisfied by the clipper of a shaving apparatus

If a hair clipper is to be constructed so that it is suitable for shaving it must first satisfy the following requirements:

1) The thickness of the lower comb must be as small as possible. With a thickness of even several tenths of a millimeter the hairs could no longer be cut short enough.
2) The two combs must fit together perfectly. A distance of several hundredths of a millimeter between them would already cause pulling of the hairs, and the finest hairs would fail to be cut.
3) The cutting speed must be very high. This is not only necessary for rapid shaving, but it is found that the hairs are more easily cut at high cutting speeds. When the cutting speed is sufficiently high a slight dullness of the cutting teeth after long usage is found to have no unfavourable effect on the action of the clipper, if care is taken that the sliding surfaces of the two combs continue to fit perfectly against one another. The material of the teeth then also becomes of only secondary importance so that it may be chosen according to other requirements than that of the greatest possible hardness.

It will appear later how these points have been taken into account in the construction of the Philips dry shaver.

Construction of the Philips dry shaver

The cutting mechanism of the Philips dry shaver "PhiliShave", like that of a hair clipper, consists of two parts, the stationary part which is pressed against the skin and the moving part which cuts off the hairs. The latter part does not execute an oscillating motion as in a hair clipper, but a rotating motion. Moreover it does not have the form of a comb with a large number of cutting teeth, but that of a fraise with only three knives, which rotates at a high speed and which can be easily pressed against the surface of the stationary comb (see *fig. 3*).

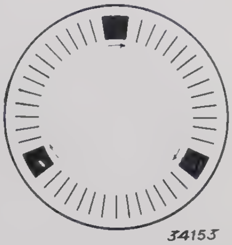

Fig. 3. Diagram of the rotating cutting element of the Philips dry shaver "PhiliShave". Three knives rotate around a circular comb.

The rotating construction has the advantage over the oscillating construction according to fig. 1 that a considerably greater speed can be obtained, while the presence of only three knives makes possible a statically determined construction in which the knives lie against the running surface with a constant pressure, even when the wear on the different knives is not exactly the same.

The way in which this statically determined construction is obtained will be explained in the description of the driving mechanism. We shall however first study the shaving element itself in more detail.

The shaving element

A cross section of the shaving element is shown in *fig. 4*. The stationary part consists of a cylindrical cap with a raised bottom. The lower edge thus forms a ring with a U-shaped cross section. The cap is made of very high quality steel and has a rigid shape, so that it is possible to give it a thickness

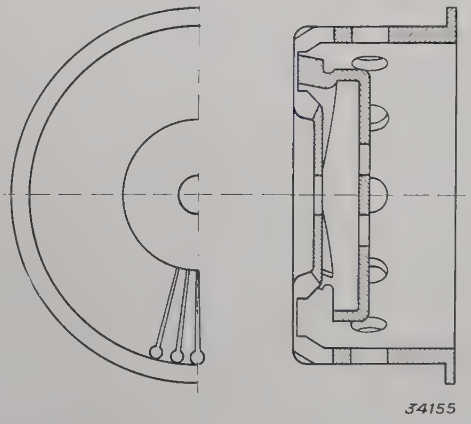

Fig. 4. Cross section of the cap and fraise. The form of the slits is indicated on the left.

of less than 1/10 mm at the apex of the U-shaped ring. The ring is provided with a large number of radial slits, into which the hairs are guided during the shaving process.

The slits are not only found on the under surface, but they are continued up both sides of the ring. On the outer side they are somewhat wider toward the outside surface so that the hairs enter more easily. The continuation of the slits on the inner side of the ring also helps to catch the hairs: the skin is stretched taut by the depression in the cap so that the hairs stand erect and enter the slits more easily.

The fraise is kept centred by the ring-shaped track; any other centring device was found to be unnecessary and even detrimental. In designing the fraise every attempt was made to keep the friction small so that a small motor could be used and in that way the weight of the apparatus could be kept low. For that reason bronze was chosen as material for the knives. Because of the high speed the use of this relatively soft material presents no difficulties. It was found by experience that the knives undergo no appreciable wear when care is taken that they have slight play in a radial direction. The knives are therefore made slightly shorter than the width of the ring-shaped track.

The fraise turns at a speed of 10 000 r.p.m. Since the mean diameter of the circle on which the knives lie is 12 mm the velocity of the knives is

$$v = \frac{10\,000}{60} \cdot \pi \cdot 0.012 = 6.3 \text{ m/sec.}$$

This must be considered as a very high speed when it is noted that the maximum cutting speed of shaving apparatus with oscillating combs is 1 m/sec, and usually no higher than 0.5 m/sec.

The driving mechanism

Fig. 5 shows the driving mechanism of the fraise. The rounded knob of a coupling piece K of "Philite" is pressed against the centre of the fraise by the spring V. The driving force of the motor shaft M is transmitted by means of the two pins S of the coupling piece which fit loosely into two holes in the fraise.

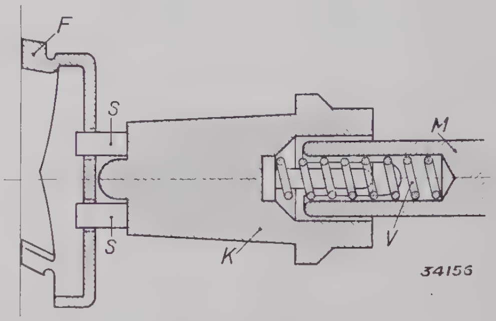

Fig. 5. Driving mechanism of the fraise F with motor shaft M. V spring, K coupling piece of "Philite", S pins.

As may be seen the transmission has been kept very flexible, which was necessary in order not to hinder the radial play of the fraise. The coupling piece K is flexibly coupled to the motor shaft M, while the fraise is flexibly coupled with the coupling piece. The result is that the coupling between the motor shaft and the fraise has the character of a cardan joint. The pressure of the spring V is about 20 g., and it is equally divided among the three knives, due to the flexible transmission.

A clear view of the different parts of the driving mechanism and their coupling is given in the photographs of *figs. 6* and 7 of the separate parts and of the whole apparatus cut open. It may also be seen from these photographs how the use of "Philite" as a structural material makes possible a neat and compact unit.

The motor

In order to keep the apparatus as small as possible the "Philite" housing serves as grip and at the

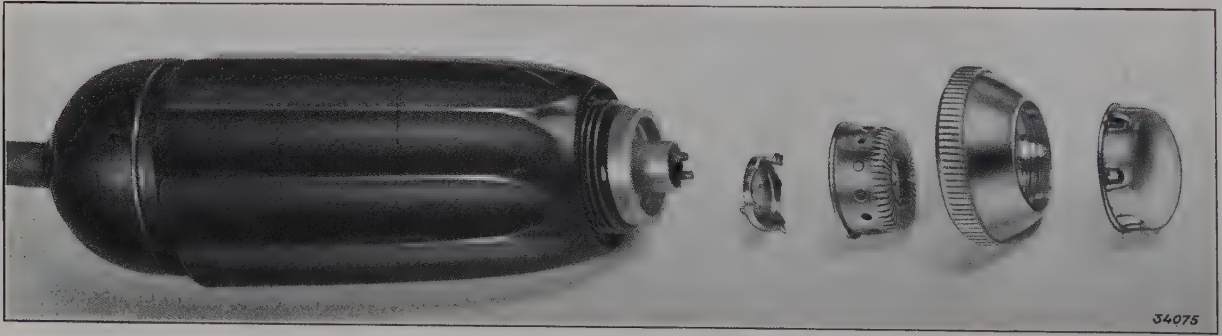

Fig. 6. Parts of the Philips dry shaver "PhiliShave". Left to right: the motor in a "Philite" housing with the projecting pins of the coupling piece, the fraise, the cap, a fastening nut, a cover for protecting the cap when not in use.

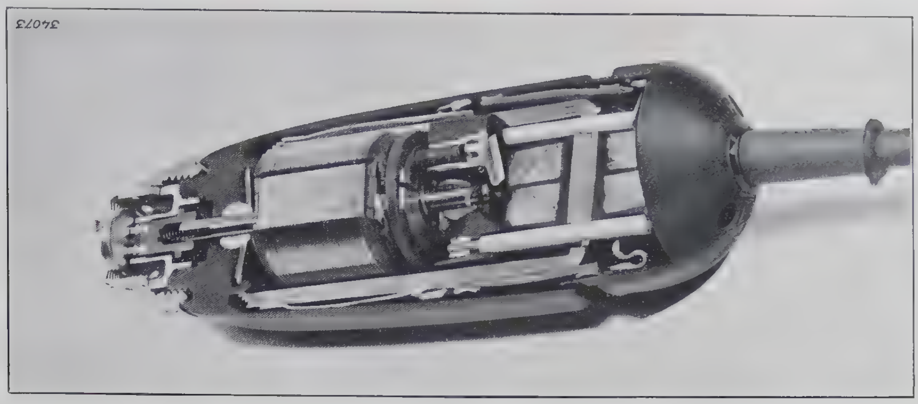

Fig. 7. Cross section of the Philips dry shaver.

same time as a frame for the motor. A collector motor is used which is suitable for direct and alternating current. The collector is in the form of a disc with three segments and may clearly be seen in fig. 7. It is also clear from this figure that the characteristic of flexibility is again present in the bearings, which are of the so-called self adjusting type; the bushings are spheres with a hole bored through them, and can thus easily turn in the corresponding depressions of the housing. In this way provision is made that any slight inaccuracy in the shape of the housing cannot cause the motor to run heavily, which is very important with the high speed of 10 000 r.p.m. The bearings are of a porous self-lubricating bronze [1]. Near each bearing there is also a small piece of oil-soaked felt. Together with the self-lubricating bronze a system is thus obtained which needs no attention.

The whole construction is such that the necessary electrical connections are automatically made in assembling the motor. The motor consumes about 8 W and is suitable for direct and alternating current from 100 to 135 volts. Higher voltages may also be used by connecting a resistance in series with the motor. A variable resistance is built into the plug-in contact for this purpose, and it can be adjusted by means of a turning switch. The axis of this switch projects between the pins of the contact and is provided with a groove so that it can be turned with a screw driver or other suitable instrument (a coin for instance). The following voltages can be used:

100—135 volts (125 volts nominal),
140—190 volts (165 volts nominal),
200—260 volts (225 volts nominal).

The nominal voltage may be read off through a small opening in the plug (see *fig. 8*).

Use of the dry shaver

The apparatus is pressed directly against the skin and moved over the surface of the skin with a circular motion. Since there are slits in all directions it is not necessary to turn the apparatus. The hairs are as it were "approached" from all directions and are thus surely led into the slits.

The hairs which have been cut off are collected inside the cap and thus do not fall upon the clothing. This makes it possible to shave after dressing without taking any special precautions. The hairs can easily be removed from the cap simply by blowing through the openings.

After the apparatus has been in use for some time it becomes necessary to clean the cap from the deposit caused by perspiration etc. The fastening screw of the cap must be loosened and cap and knives cleaned with a soft brush or disinfected with a little alcohol. The running surface need not be lubricated after this treatment. The oil always present on the skin provides sufficient guarantee that the moving parts will never become dry.

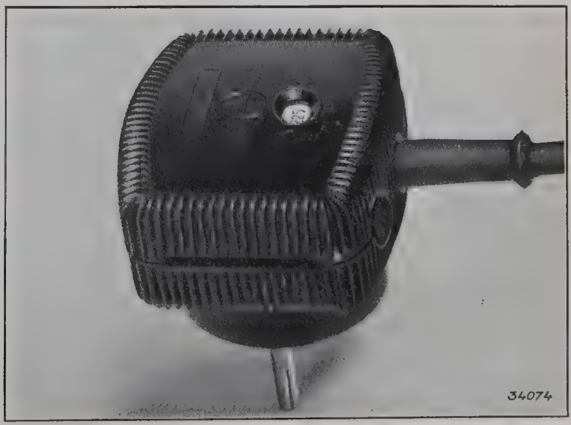

Fig. 8. Plug-in contact of the Philips dry shaver. The contact contains a built-in variable auxiliary resistance. The latter is here shown adjusted, so that the apparatus can be used with a mains voltage of 225 volts.

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[1] *Cf.* Philips techn. Rev. 4, 328, 1939.

Safety

Since the apparatus is connected with the mains and brought into contact with the skin, the greatest care has been taken that there shall be no danger in the use of the apparatus, in case certain parts should become out of order. It might for example occur, due to the breaking of a wire, that the body of the motor was under a tension. Even such a defect would not bring the user into contact with the mains, because the motor is completely surrounded by a "Philite" housing, while the cutting element itself, which is in contact with the skin, is connected with the motor axle only through an insulating coupling piece of "Philite".

Another point to which attention has been given is that of radio interference which might be caused by the motor, as by all other collector motors. The motor itself can relatively easily be rendered free of interference by the well-known method [2]). When however the apparatus is taken in the hand new interferences appear. They are caused by a capacitative coupling between the collector (which is under the highest interference voltage) and the hand which is practically earthed for high-frequency voltages.

This interference can be removed by shielding the collector. The stator already fulfils this function to a certain extent, but this is not sufficient. Adequate shielding is obtained by an extra pair of plates connected electrically with the stator and forming with it a closed network around the collector and armature.

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[2]) *Cf.* Combating radio interferences, Philips techn. Rev. **4**, 237, 1939.

THE TESTING OF LOUD SPEAKERS

by R. VERMEULEN.

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For judging the quality and for comparing different loud speakers it is desirable to make use of quantitative data, such as the distortion and the frequency characteristic. The methods used in the Philips laboratory for the rapid determination of these factors make up the subject of the first part of this article. In the second part the fundamental problem of the conditions under which the measurements on the loud speaker must take place is dealt with. The measurement of the direct sound alone is discussed as well as the measurement of the total sound radiation and a measurement in which a certain combination of direct and indirect sound is used as a basis.

The highest instance in the judging of the quality of reproduction of a loud speaker is the ear of the listener. The most natural method for the testing and comparison of different loud speakers consists simply in listening to the music or speech reproduced. This method has however the obvious imperfection, that the judgment can only be of a qualitative nature, and that any slight deviations are either entirely unnoticed or observed in such a way that it is difficult to draw any conclusions about their cause. It is therefore desirable to supplement the listening tests with measurements which permit a more accurate and objective judgment of the quality of the reproduction.

The first question which arises is, what must we measure? Or in other words, by what quantities is the quality of the reproduction determined? In the main there are two such factors:

1) The distortion, which constitutes a measure of the non-linear distortion in the loud speaker. It is usually defined by the equation:

$$F_1 = \sqrt{\frac{a_2^2 + a_3^2 + a_4^2 + \dots}{a_1^2}}\,, \quad . \quad . \quad (1)$$

where a_1 and $a_{2,3,4\,\dots}$ indicate the amplitude of the fundamental and of the overtones occurring in the loud speaker, respectively.

2) The frequency characteristic, which indicates the sound intensity produced by the loud speaker when alternating voltages of different frequencies are applied to its terminals.

For ideal reproduction $F_1 = 0$, and the frequency characteristic must be flat, *i.e.* the sensitivity of the loud speaker must be the same for all frequencies. The deviations from these conditions found in practical cases, while they do not permit the drawing of any conclusion about their effect on the reproduction without the aid of listening tests, do however make possible a comparison of different loud speakers and particularly an estimation of the influence which may be expected from any change in the construction.

In this article we shall concern ourselves with the manner in which the factors mentioned are obtained. In addition to the apparatus necessary for this purpose, the problem of the conditions under which the measurements must be carried out also deserves attention. This question will also be discussed in detail.

The measurement of sound

The simplest method and the one most often applied for the determination of sound intensities makes use of a microphone introduced into the sound field. If the microphone is calibrated, *i.e.* if the relation is known between the sound pressure and the microphone voltage generated thereby, the measurement of sound is reduced to the measurement of an electric voltage, which can be done with an amplifier and a voltmeter.

A condenser microphone (*fig. 1*) is usually used as measuring microphone, one of the reasons being that the calibration can in this case be carried out in a simple way, namely, by allowing an electrostatic force instead of the sound pressure to act on the membrane. In an earlier article in this periodical [1]) this calibration was discussed in detail. It is sufficient now to point out that the calibration takes place in two steps. We first determine the voltage which the microphone produces when an alternating force of a given amplitude and frequency acts on the membrane. A correction must then however be introduced, due to the fact that the microphone itself causes a distortion in the sound field, so that the variations in pressure found by measuring the voltage, are not exactly the same as in the undistorted sound field. This correction depends only on the shape and dimensions of the microphone, and need therefore only be determined once for a given type of microphone. The determination may be by calculation or experimentally, by comparison of the results of the measurement with those obtained with a Rayleigh disc (see the article cited in footnote [1]).

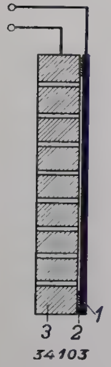

Fig. 1. Diagram of a condenser microphone. The membrane *1* is placed at a very small distance (16 μ) from the rigid plate *3*. The separation is determined by the thickness of the ring *2* lying between. *1* and *3* together form a condenser whose capacity varies upon vibration of the membrane. With constant charge voltage variations hereby occur between *1* and *3*, which after amplification may be measured. Plate *3* is provided with a number of holes in order to prevent the rigidity of the cushion of air between *1* and *3* decreasing the sensitivity of the microphone.

In *fig. 2* some measuring microphones are shown. The microphone amplifier is set up at some distance from the microphone, in order to avoid disturbance of the sound by the amplifier cabinet. The amplified voltage of the microphone can be measured with a voltmeter.

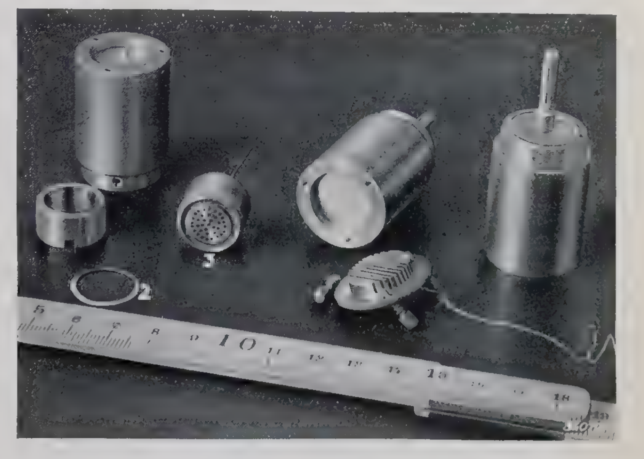

Fig. 2. Condenser microphone. Among the parts on the left may be seen the rear electrode *3*, the intermediate ring *2* and the membrane stretched in its housing *1* (see fig. 1). In front of the middle microphone lies an auxiliary electrode in the form of a grid, which is used in the calibration of the microphone to exert an electrostatic force of known magnitude on the membrane.

Determination of distortion

The condenser microphone causes no appreciable non-linear distortion of the signal. If a pure sinusoidal voltage is fed to the loud speaker (fundamental), any overtones which appear in the microphone voltage, and whose intensity can be measured separately with a suitable analysing instrument, must be ascribed exclusively to the distortion in the loud speaker. From the individual measurement of each overtone the distortion F_1 can be calculated according to equation (1). The factor F_1 can also, however, be measured directly when the microphone voltage is divided into two parts by means of filters, one of which parts contains only the fundamental and the other only the overtones. The energy of these two signals can be measured with the aid of thermocouples. By means of a compensation circuit, the principle of which is given in *fig. 3* and is explained in the text beneath, F_1 can be read off directly from a scale.

It must be mentioned in passing that the degree of distortion is indicated not only by the factor F_1, but also by a factor defined by the formula:

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[1]) J. de Boer, Absolute sound pressure measurements, Philips techn. Rev. **1**, 82, 1936.

$$F_2 = \sqrt{\frac{2\,a_2^2 + 3\,a_3^2 + 4\,a_4^2 + \dots}{a_1^2}} \quad . \quad (2)$$

In this formula greater weight is assigned to the higher harmonics, in agreement with the physiological fact that the higher harmonics lead more quickly to an unpleasant lack of purity than to the low ones. F_2 like F_1 can be determined from the separately measured overtones, or directly by means of an arrangement like that of fig. 3, when an amplifier V is used whose amplification increases proportionally with the frequency.

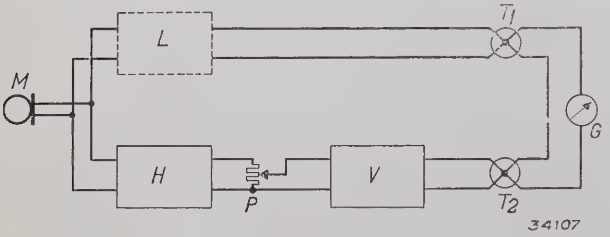

Fig. 3. Sketch showing the principle of the compensation circuit for direct measurement of the distortion factor F_1. The filter L which passes only low frequencies passes only the fundamental (a_1) of the voltage of the microphone M. The energy of this voltage is measured by the thermocouple T_1. The overtones of the microphone voltage are sifted out by the filter H passing only high frequencies, and they are then brought to about the same intensity as the fundamental in the amplifier V. The potentiometer P is so adjusted that the output voltages of T_1 and T_2 exactly compensate each other, which is ascertained by means of the galvanometer G. The setting of P then provides a measure of the ratio of $(a_2^2 + a_3^2 + a_4^2 + \dots)$ and a_1^2. The filter L can also be omitted. One then actually measures the ratio of

$$(a_2^2 + a_3^2 + a_4^2 + \dots) \text{ and } (a_1^2 + a_2^2 + a_3^2 + \dots),$$

by which the value of F_1 is also determined unambiguously.

Recording the frequency characteristic

In order to record the frequency characteristic the voltage of the measuring microphone is measured while the frequency of the voltage on the loud speaker is varied. The voltage measured will at any frequency be proportional with the electrical energy supplied to the loud speaker. One would therefore prefer to keep this energy constant during the recording of the characteristic. This, however, requires rather elaborate measures, since the impedance of the loud speaker changes with the frequency. In practice therefore either the amplitude of the voltage or that of the current is kept constant during the measurements, and one then obtains two frequency characteristics which will in general be different. The characteristic recorded at a constant voltage amplitude is important when the loud speaker is to be connected with an amplifier which gives a constant output voltage, as for example for radio distribution. If however the final amplifier gives a constant current (as in ordinary receiving sets with pentode) it is clear that the loud speaker to be used must be judged according to the characteristic recorded with constant current.

The voltage with variable frequency required for recording the characteristic is produced by a tone generator, the frequency of which can be varied within very wide limits (25 to 16 000 c/s.) by means of a rotating condenser. The voltage of the tone generator is supplied to the loud speaker *via* an amplifier. This amplifier must not of course falsify the loud speaker measurement, and must therefore have a perfectly flat frequency characteristic and only very slight distortion. Furthermore it must be able to give, as desired, a practically constant output voltage or output current, which means that the internal resistance must practically be made zero or infinite.

The point-by-point determination of a frequency characteristic is a time-consuming operation, since, because of the sudden variation which may occur in the curve, it is necessary to measure very many points. Since such measurements must be carried out repeatedly in the Philips Laboratory, an installation is used which automatically records the required frequency characteristics. The principle of the apparatus is very simple (*fig. 4*). A synchronous motor turns the variable condenser of the tone generator so that the frequency of the loud speaker current varies continuously, while the amplified voltage of the measuring microphone is recorded by a recording voltmeter on a band moving at a constant velocity. It is however desirable to draw the frequency characteristic in logarithmic coordinates in order to do justice to all parts of the

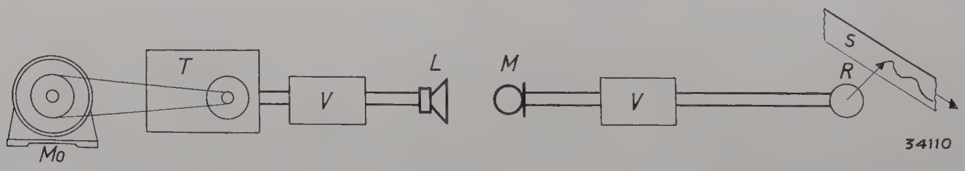

Fig. 4. Diagram of the apparatus for the automatic recording of frequency characteristics, Mo motor, T tone generator, V amplifier, L loud speaker, M microphone, R recording voltmeter, S moving band.

extensive frequency and intensity range [2]). As to the frequency, a logarithmic scale is obtained by arranging that the driving mechanism of the tone generator is such that the angle between any two positions of the mechanism is always proportional to the ratio between the two corresponding frequencies. In other words, with motion at constant velocity the frequency passes through an equal number of octaves in equal time intervals, and an octave thus always has the same width on the measuring band.

For the voltages to be measured, logarithmic registration is obtained in the following way [3]). The voltage to be measured is supplied to an amplifier whose amplification can be regulated by a so-called logarithmic potentiometer. This is a potentiometer in which the resistances between the successive contacts form a geometrical progression (see *fig. 5*); a rotation of the contact arm through a given angle is always followed by a change of the output voltage by the same factor, no matter what the initial position may be. With a given input voltage of the amplification there is therefore proportionality between the angle of rotation of the potentiometer and the logarithm of the output voltage delivered. The converse is also true: in order to obtain a *constant output voltage* the potentiometer must in each case be set, so that its position is proportional to the logarithm of the input voltage. This "volume control" is automatically obtained by causing the shaft of the potentiometer to be driven simultaneously by two magnetic couplings which turn in opposite directions at a constant velocity (see *fig. 6*), one of which is more strongly magnetized when the output voltage of the amplifier is greater, the other when it is smaller than a constant comparison voltage serving as zero level. In the first case therefore coupling *1* dominates and carries the potentiometer shaft along with it, so that the output voltage is lowered until it reaches the value of the comparison voltage. At that moment the two couplings have the same magnetization, the two couples are in equilibrium and the potentiometer remains

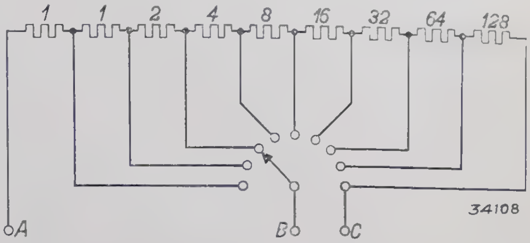

Fig. 5. Logarithmic potentiometer. At each jump of the contact arm the resistance between *A* and *B* increases by the same factor *f* (here assumed to be 2). The potentiometer in the apparatus described has 60 steps. There are four such potentiometers with $f = 1.122$, 1.059, 1.029 and 1.011 respectively. The voltage scale then covers $60 \times f = 60$ db; 30 db, 15 db and 6 db respectively. Moreover such potentiometers are in general use as volume regulators, in radio sets for example, for the purpose of obtaining a uniform variation of the subjective sound intensity according to the law of Weber and Fechner.

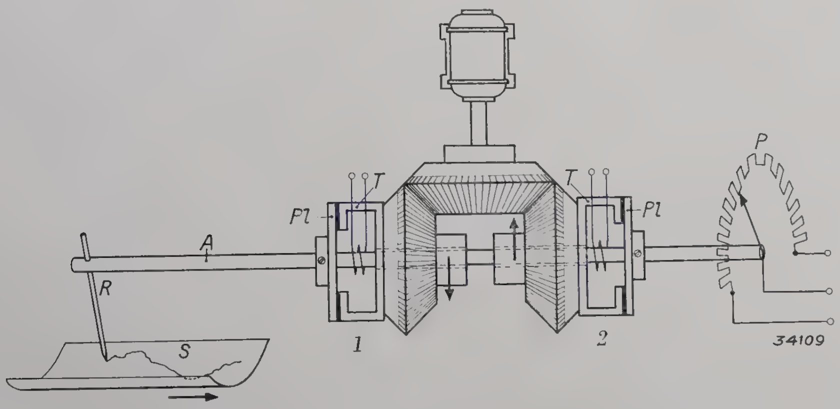

Fig. 6*a*. Driving mechanism of the logarithmic potentiometer [4]) by means of two magnetic couplings *1* and *2*. The iron discs *Pl* are rigidly fastened to the shaft *A*, which bears the arm of the potentiometer *P* and the recording style *R*, and lie in slight frictional contact with the drums *T* which turn continually in opposite directions. When the magnet in coupling *1* is more strongly magnetized than that in *2* the shaft *A* is carried around in one direction due to the greater pressure and the consequent increased friction between *T* and *Pl* of coupling *1*, and *vice versa*. On the recording film *S* the position of the potentiometer is registered. The mechanism reacts extremely rapidly. When the drums *T* are allowed to rotate at their maximum velocity the whole voltage scale (60 steps of the potentiometer, see fig. 5) is passed over in $^1/_{10}$ sec. In ordinary cases, in order not to subject the couplings to unnecessary wear, a velocity of $^1/_{10}$ of the maximum is used.

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[2]) R. Vermeulen, Octaves and decibels, Philips techn. Rev. **2**, 47, 1937.

[3]) *Cf.* also: E. C. Wente, E. H. Bedell, K. D. Swart jr. J. Acoust. Soc. Am. **6**, 121, 1935; E. Meyer and L. Keidel, E.N.T., **12**, 37, 1935; H. J. von Braunmühl and W. Weber E.N.T. **12**, 221, 1935.

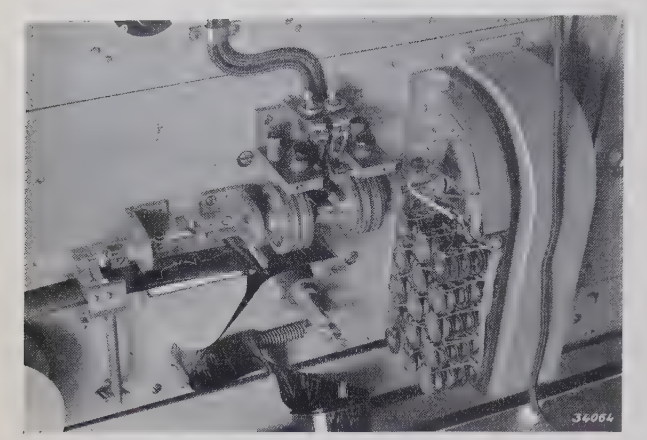

Fig. 6*b*. Photograph of the mechanism sketched in fig. 6*a*. On the right may be seen two of the potentiometers of fig. 5 for a scale of 60 and 30 db, respectively.

stationary. When the output voltage is lower than the comparison voltage, coupling *2* takes over and the potentiometer is taken along in the opposite direction until once more the output voltage is equal to the comparison voltage. The arrangement works very rapidly, so that rapid variations of the input voltage of the amplifier (steep parts of the frequency characteristic to be measured) are followed.

A style is attached to the shaft of the potentiometer, which records the position of the potentiometer on the above mentioned band, which moves in the direction of the shaft (fig. 6). The band is a piece of "Philimil" film [4]), in the black covering layer of which a transparent line is scratched by the recording style. The record obtained is reproduced by photographic printing, and the scale of frequencies and voltages is introduced on the positive.

In *fig. 7* is a photograph of the complete installation which clearly shows the different parts here discussed.

Further consideration of the conditions of measurement

In the above we have continually spoken of "the" distortion and "the" frequency characteristic of a loud speaker. Actually however the determination of these factors for a single loud speaker may produce very varied results. In the first place

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[4]) This film is used in sound recording by the Philips-Miller system (Philips techn. Rev. **1**, 230, 1936). The "Philimil" film has for our purpose the advantage that it is very easy to work with.

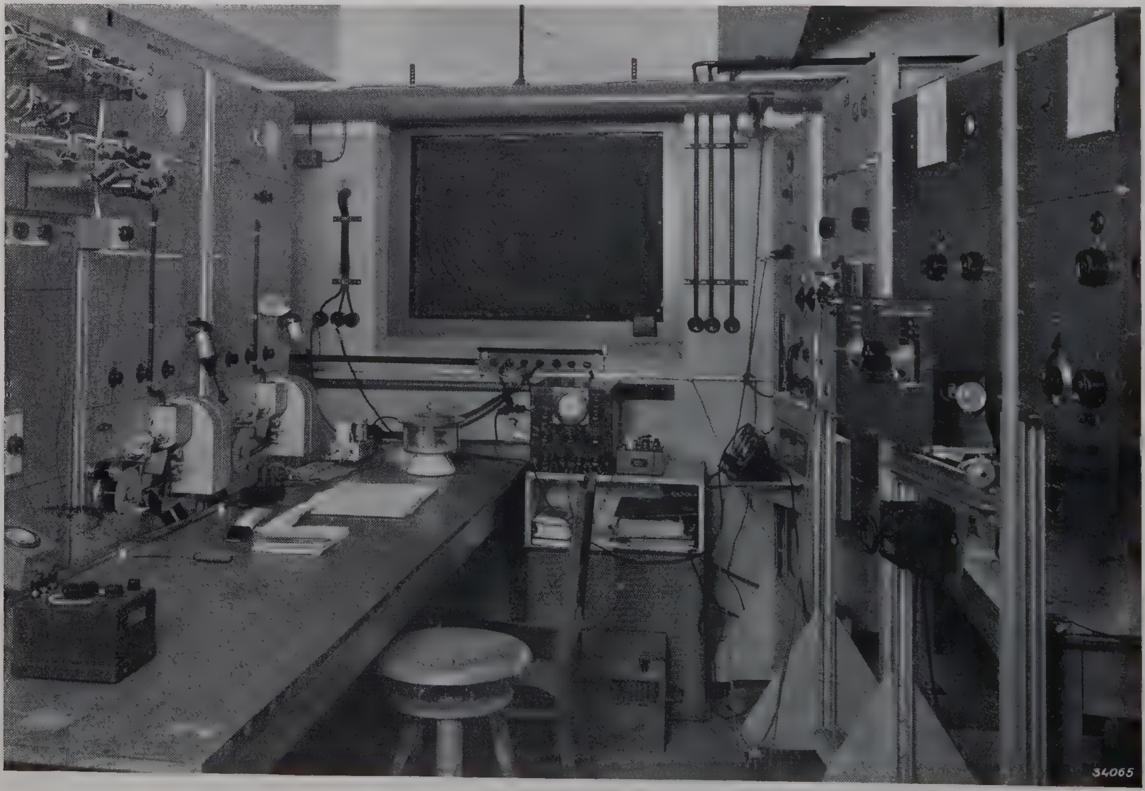

Fig. 7. The complete installation for automatic recording of frequency characteristics. On the left the recording apparatus proper, in duplicate. On the right two tone generators which supply the voltage for the loud speaker, and behind them the amplifier for this voltage. On the wall to the right and left of the window a series of contacts and binding posts which provide connections with other rooms where loud speakers may be set up for measurement.

the sound radiation of the loud speaker is not the same in both directions, and in the second place, under ordinary circumstances, in addition to the direct sound of the loud speaker, there is also the indirect sound, which reaches the microphone only after one or more reflections against the walls, etc. How must the measurements be arranged in order to obtain results which really do form a measure of the usefulness of the loud speaker?

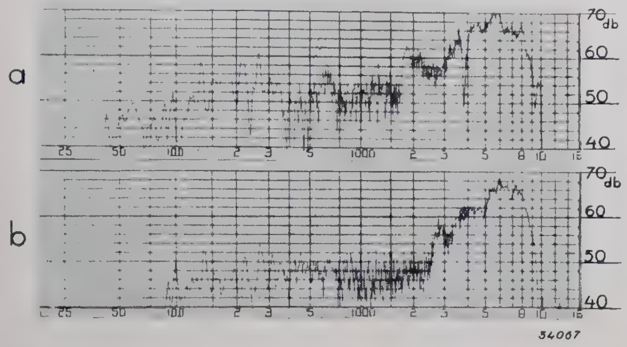

Fig. 8. Frequency characteristics of two different loud speakers recorded in an ordinary living room. The combination of direct and indirect sound causes numerous irregularities which render the interpretation of the curve practically impossible.

It would seem obvious that the measurements should be carried out under the same conditions as those under which the loud speaker is used in practice, thus, for example in an ordinary living room. The result of such a measurement is given in *fig. 8*. Due to the interference of direct and indirect sound numerous irregularities are obtained in the frequency characteristics, and the resulting diagram is so little characteristic of the loud speaker used that one could say with some truth that fig. 8 represents a measurement of the properties of the room rather than of the loud speaker.

Measurement of the direct sound

In the open air

In order to gain some information about the loud speaker itself, it is thus necessary in the first place to measure the direct sound alone. All reflecting walls must be removed from the sound field, which makes it advisable to carry out the measurements out of doors. When this is done only the ground remains which might still cause unwanted reflections. This difficulty can however be met by placing the loud speaker and microphone very high, for instance projecting over the edge of a high roof. Such an arrangement is shown in *fig. 9*.

Because of the above-mentioned dependence of the sound radiation on the direction, the frequency characteristic and the distortion must be measured not only at the axis of the loud speaker, but also in directions at different angles to the axis. The loud speaker must therefore be placed on a turn-table so that it can be set at different angles with respect to the fixed connecting line between the microphone and the centre of the turn-table.

For a complete record the measurements should be done in all possible directions. The investigation would however thus become extremely elaborate, and moreover the result (a whole series of characteristics) would be very difficult to judge. For these reasons it is very often considered sufficient to take a measurement on the axis of the loud speaker and one in a direction at 45° to this axis. Two such frequency characteristics are reproduced in *fig. 10*. These measurements are supplemented

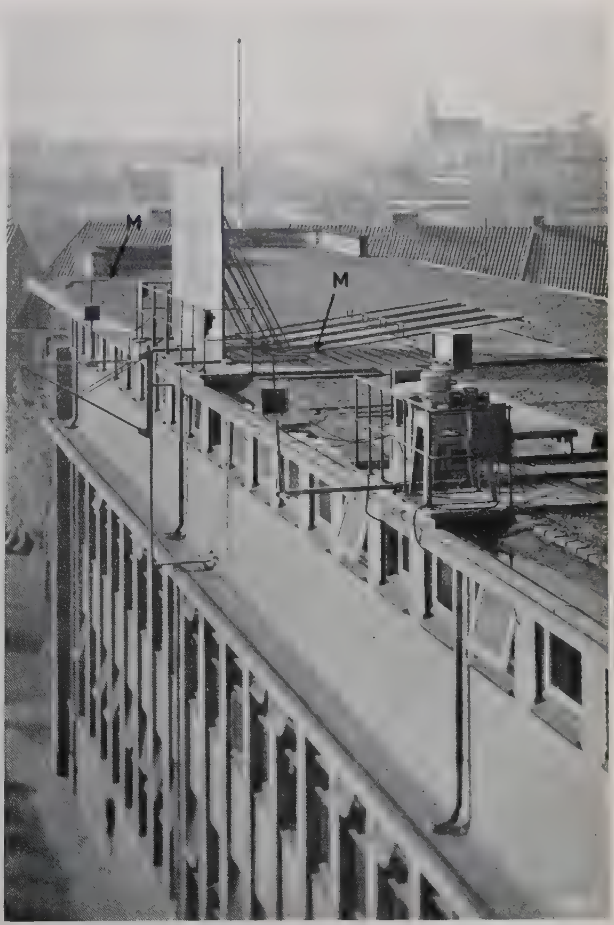

Fig. 9. Set up of loud speaker and measuring microphone (M) in the open air. The loud speaker (radio set) is placed on a turntable. In front of it is the microphone amplifier. For the avoidance of interferences due to induction the connections from the microphone to the amplifier are shielded by a tube. The large plate seen in the background is used as an "infinitely large" baffle in the investigation of separate loud speaker systems, *i.e.* when the effect of cabinet or baffle of the loud speakers must be excluded. In order in such cases also to be able to measure in different directions, the measuring microphone with its amplifier is fastened to a rotating arm.

by a determination of the sound intensity, keeping the frequency constant and varying the direction continuously. In this way a diagram is obtained of the directional distribution of the sound intensity which may be compared with light distribution curves such as are customarily recorded for sources of light. The directional diagram must be recorded for different frequencies (for instance 1 000, 2 000 and 4 000 c/s), since loud speakers generally show a selective directional effect [5]). The direction diagrams are recorded with the same recording apparatus as the frequency characteristics, whereby only the adjustment of the tone generator remains unaltered while the loud speaker is turned continuously.

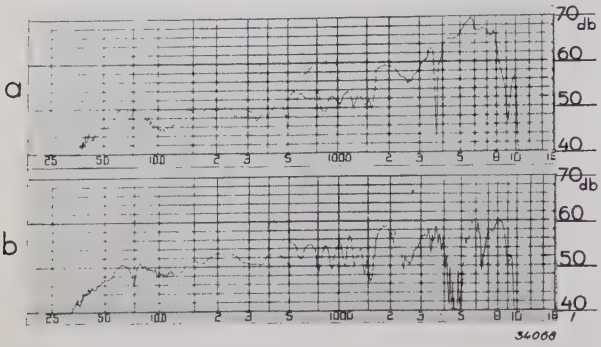

Fig. 10. Frequency characteristics of a single loud speaker measured in the open air at angles of 0° and 45°, respectively. The loud speaker is the same as in the case of fig. 8*a*, but was here placed in the large baffle of fig. 9.

The "soft chamber"

Measurement out of doors has two objections. The results are influenced by extraneous noise, and one is dependent upon the weather. As for the first objection, it may be met by introducing a filter behind the microphone, which only passes the frequency which is supplied to the loud speaker. There is however no solution to the difficulty of rain and wind. There have therefore been made numerous attempts to imitate out-of-doors conditions in a room, a so-called "soft chamber". For this purpose the walls of the room to be used must be covered with a material which absorbs sound as completely as possible. The available technical damping materials have been found inadequate. With the very best materials of this kind it is scarcely possible to attain absorption coefficients higher than 70 per cent. The effect of the remaining reflections on the measurements can be roughly calculated in the following way. The variations in pressure in a reflected sound wave, with the absorption coefficient mentioned, amount to $100\sqrt{1-0.7} = 55$ per cent of those in the original wave. Let us assume that the path of a reflected beam which strikes the microphone is on the average five times as long as the path of the direct beam; as the intensity of the sound decreases with the square of the distance and the sound pressure proportionally to this distance, the variation in pressure at the microphone in the reflected wave is $^1/_5 \times 55 = 11$ per cent of the direct beam. In an ordinary rectangular room there are six reflecting surfaces, and thus the same number of beams reflected once. In the most unfavorable case all reflected rays can be in phase with the direct ray at the microphone, or all of them will be in the opposite phase at that point. The variations in pressure measured may then in the first case amount to $100 + 6 \times 11 = 166$ per cent of the undisturbed value, and in the other to $100 - 6 \times 11 = 34$ per cent.

One must therefore have a much higher absorption coefficient than 70 per cent. It may be seen in *fig. 11* how the wall covering of the „soft chamber" is actually constructed. An absorption coefficient of about 97 per cent has been reached in this case.

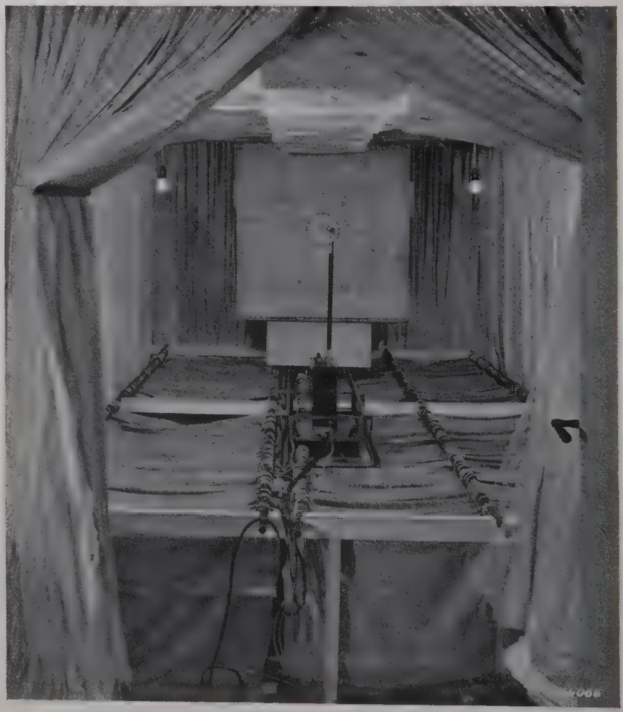

Fig. 11. The "soft chamber" in the Philips laboratory. In order to make the walls as sound absorbent as possible they are first covered with a layer of a technical absorbent material (slag-wool). In front of this layer and perpendicular to the walls strips of crepe paper $^1/_2$ m wide are hung $1^1/_2$ cm apart. On the floor this covering is replaced by a series of curtains hung close to each other, which can be pushed to one side when it is necessary to enter the room in order to set up the measuring microphone.

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[5]) J. de Boer, Sound diffusers in loud speakers, Philips techn. Rev. 4, 144, 1939.

If the above estimation is repeated with this value maximum deviations of 20 per cent are found, which means therefore about 2 db too much or too little. This is still rather high but it is nevertheless permissible for many measurements.

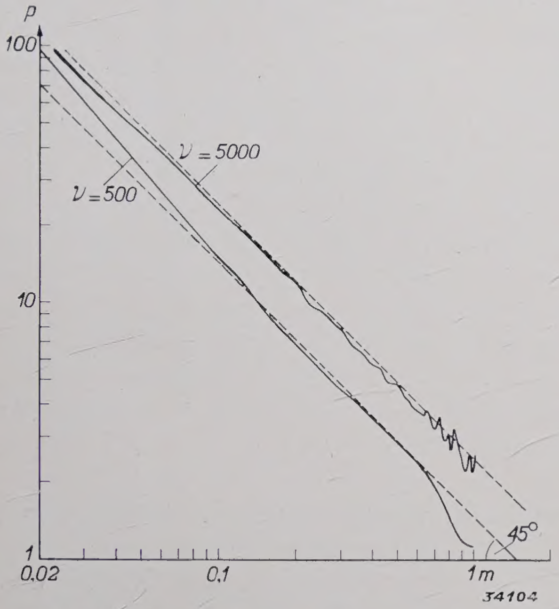

Fig. 12. Decrease of the sound pressure with increasing distance from a point source of sound measured in the chamber of fig. 11 for frequencies of 500 and 5 000 c/sec, respectively. The theoretical decrease (with an absorption by the walls of 100 per cent) is indicated in each case by a broken line.

The residual influence of the walls can also be controlled directly in a simple way, by studying the distribution of pressure around an approximately point source of sound. The sound pressure in that case, in the entire absence of indirect sound, would be independent of the angle and would decrease proportionally with the distance. In *fig. 12* is a diagram of the distribution of pressure measured. As may be seen the theoretical variation is fairly closely approached.

We may mention a general consideration for all measurements of the direct sound from loud speakers. In order to render the influence of disturbances as small as possible, it is desirable to measure at high intensities, and it would therefore seem advisable to place the microphone close to the loud speaker. This is, however, impossible for the following reason. Since an ordinary loud speaker is anything but a point source, interferences may occur between the waves which are radiated by different parts of the cone. If therefore the microphone is shifted along the axis of the loud speaker, successive minima and maxima of intensity are observed. Only at distances greater than two or three times the diameter of the radiator is this effect diminished to such a degree that the measurements experience no appreciable effect. For the investigation of ordinary radio loud speakers, therefore, it is a general rule that the microphone must stand at least 1 m from the loud speaker.

Total sound radiation of a loud speaker

In certain respects analogous concepts can be used in the study of sources of sound as in that of sources of light. This was noted above in the discussion of directional distribution. Another quantity which is always used in light technology and for which an analogue can be conceived in acoustics is the total light flux. The analogue is obviously the total sound radiation produced by a loud speaker. This quantity is particularly important when it is a question of "filling a room with sound", *i.e.* when the indirect sound contributes a considerable portion to the formation of the sound field. In the extreme case when the indirect sound dominates completely over the direct (*i.e.* when there is a very long reverberation), even the average density E_m of the sound energy in the room is still dependent only on the total sound radiation W:

$$E_m = 0{,}072 \frac{T}{V} \cdot W \quad . \; . \; . \; . \quad (3)$$

T and V are the reverberation time and the volume of the room, respectively [6]). The total sound radiation can be determined in different ways. The most direct method consists in recording the sound intensity I_a in the above-described way as a function of the angle a to the axis, and calculating the total sound radiation W by means of the following formula (see *fig. 13* for its derivation):

$$W = 2\,\pi\,r^2 \int_0^{\pi} I_a \sin a \,\mathrm{d}a \quad . \; . \; . \quad (4)$$

It is unnecessary to state that this method is quite elaborate. Another method is the following. The electrical power taken up by the loud speaker is determined a) under normal conditions, *i.e.* when it is radiating sound, and b) when radiation has been made impossible by fixing the loud speaker coil. The difference may be considered as the acoustic power radiated. Apart from the lack of accuracy of such a differential measurement (the acoustic power amounts to only a few per cent of the total [7])) there is also the objection that the mechanical losses which occur during the movement of the coil and which are not accurately known, are also included in the difference of power found.

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[6]) The equation may easily be derived from equations (4) and (5) in the article by A. Th. van Urk, Auditorium acoustics and reverberation, Philips techn. Rev. **3**, 65, 1938.

[7]) J. de Boer, The efficiency of loud speakers, Philips techn. Rev. **4**, 301, 1939.

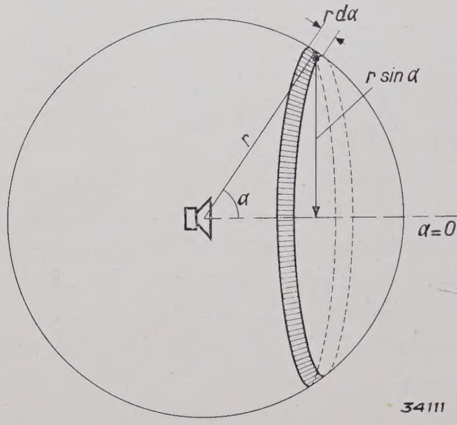

Fig. 13. Since we may consider the axis of the loud speaker ($\alpha = 0$) as the axis of symmetry of the sound field, the same sound intensity I_α will be found at all points on the shaded segment of the sphere. The area of the segment amounts to $2\pi \cdot r \sin \alpha \cdot r\, d\alpha$. The energy incident on the segment is $I_\alpha \cdot 2\pi \cdot r \sin \alpha \cdot r\, d\alpha$, and the total sound energy radiated by the loud speaker is found by integrating over all values of α. The result is formula (4).

The simplest method of determining the total sound radiation makes use of the relation given by equation (3). The conditions under which this equation is valid are realized in a so-called "hard chamber" *i.e.* a room in which the walls absorb little sound. Due to the repeated reflection of the sound waves, the sound field in this case, as is required by the formula, is practically entirely determined by the indirect sound, and in the ideal case the average energy density E_m is the same at all points in the room. To use again the analogy with light, the "hard chamber" may be compared to an Ulbricht sphere. In the acoustic example however there is an additional difficulty to be met, which does not occur in the optical case, namely the occurrence of standing waves: although the average energy density E_m which is to be measured is constant, the sound pressure nevertheless exhibits strong local maxima and minima[8]) due to interference phenomena. If it is desired to know the true average, the microphone must be moved rapidly through the chamber a distance of at least one wave length during the measurement. One may also keep the microphone stationary and cause the maxima and minima (the loops and nodes of the standing waves) to change their position rapidly and continuously. Since the positions of these maxima and minima are determined by the dimensions and shape of the chamber, by the frequency and by the directional distribution of the loud speaker, the purpose in view can be achieved in three ways. The dimensions (shape) of the chamber can be varied by means of moving reflecting surfaces (*fig. 14*); the frequency of the loud speaker current can be varied quickly over a given interval, and the directional distribution of the direct sound in the chamber can be varied, for instance by allowing the loud speaker to rotate about a vertical axis. Actually several of the possibilities mentioned are used simultaneously in the measurement.

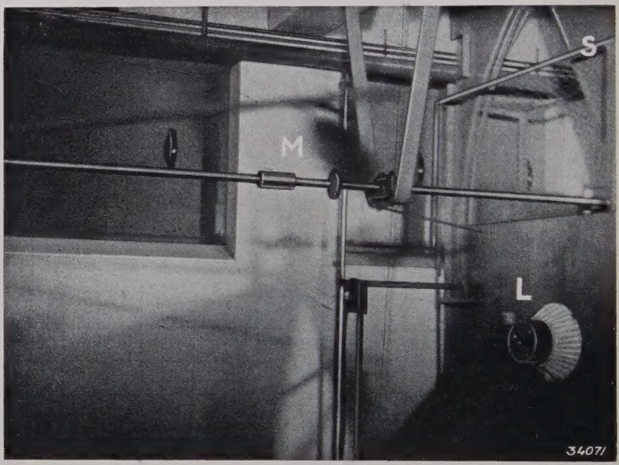

Fig. 14. A view of the "hard chamber" during a measurement. On the extreme right may be seen the reflecting surfaces in the form of sector-shaped partitions S, which rotate in their own planes. Because of its rapid motion in a wide circle the measuring microphone is badly blurred. This is also the case with the rotating loud speaker L.

Combination of direct an indirect sound

The material which has been discussed until now could be summarized briefly in the following way. The measurement of a loud speaker in an ordinary room gives a result which is too complicated due to the incalculable superposition of direct and indirect sound. In the extreme cases of a "soft chamber" and a "hard chamber" simple results are obtained, since in the one case only the direct and in the other only the indirect sound determines the result. One may now attempt to approximate a "normal chamber" (ordinary room) to some extent when the measurements are done under out-of-door conditions, while allowing the loud speaker to rotate rapidly about a vertical axis. What is then measured is the average value of the sound intensity in all horizontal directions:

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[8]) The uniform distribution of energy forms no contradiction to the observation of such maxima and minima in the sound measurements. The energy at every point is composed of a potential and a kinetic part. In the loop of a standing wave the potential part (the pressure amplitude) is at a minimum and the kinetic part (the velocity amplitude) at a maximum; at a node the reverse is true. With the condenser microphone we measure only the pressure amplitude; the kinetic part of the energy thus remains unobserved.

$$I_d = \frac{1}{2\pi} \int_0^{2\pi} I_a \, \mathrm{d}a \quad . \; . \; . \; . \; . \quad (5)$$

Compared with the measurements of I_0 alone (soft chamber), this measurement differs by the fact that the values of I_a in directions other than $a = 0$ and $\pi/4$, which manifest their presence as indirect sound in an ordinary room, are also included. With respect to the measurement of the total sound radiation (hard chamber) the difference is, as may be seen from equation (4), that the same weight is assigned to all values of I_a, while in equation (4) the term I_0 (the direct sound on the axis of the loud speaker) was determined by the relation $\sin a = 0$. It is therefore clear that the measurement of the integral (5) represents a certain compromise between a measurement of I_0 alone and a measurement of the total sound. A frequency characteristic measured in this way is reproduced in *fig. 15.*

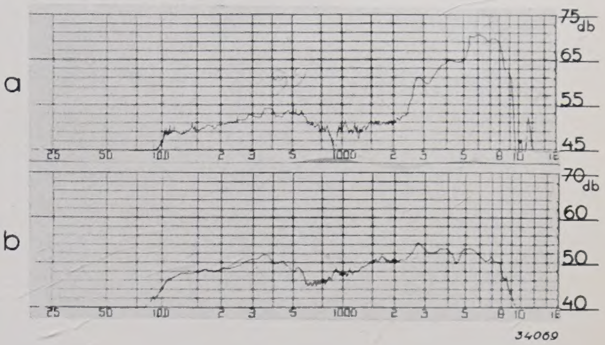

Fig. 15. Frequency characteristic recorded out of doors, *a*) with a stationary loud speaker at an angle of 0°, *b*) with a rapidly rotating loud speaker. (The loud speaker is the same as in Fig. 8b).

ABSTRACTS OF RECENT SCIENTIFIC PUBLICATIONS OF THE N.V. PHILIPS' GLOEILAMPENFABRIEKEN

1429: Balth. van der Pol and C. C. J. Addink: Orchestral Pitch. A cathode ray method of measurement during a concert (Wirel. World **44**, 441-442, May 1939).

A detailed article has since appeared in this periodical on the same subject: Philips techn. Rev. **4**, 205, July 1939).

1430: M. J. O. Strutt and K. S. Knol: Messungen von Strömen, Spannungen und Impedanzen bis herab zu 20 cm Wellenlänge (Hochfrequenztechn. u. Elektroakust. **53**, 187-195, June 1939).

Due to the inductive and capacitive coupling between supply lines and electrodes of the measuring instruments for currents and voltages — in connection with the occurrence of skin effect in connections and finite transit times of the electrons in high vacuum tubes — great difficulties occur in the measurement of alternating currents and voltages as well as impedances for waves shorter than a few metres. These difficulties are overcome by using diodes, thermocouples and hot wire ammeters of a special construction working with air expansion. Furthermore these new instruments are employed in measuring impedances of several ohms to several thousand ohms at wave lengths down to 20 cm.

1431*: A. Bouwers: Elektrische Höchstspannungen (333 pages; Springer, Berlin 1939).

In this first volume of Technische Physik in Einzeldarstellungen subjects are dealt with connected with the generation and application of electrical voltages of at least several hundred kilovolts. After a description of the different methods used for the excitation of high tensions, follows a discussion of the calculation of the electric fields which occur with various simple forms of electrodes. On page 132 a summarizing table is given of a number of field formulae hereby obtained. In addition the properties of insulating media are discussed and the different parts of which a high tension installation is composed. In a separate chapter direct and indirect methods are described for the precise measurement of high voltages, and in conclusion the most important applications are discussed. The bibliography, which consists of 324 items, makes no claim to completeness, but it does contain all the articles which were consulted in writing the book.

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*) An adequate number of reprints for the purpose of distribution is not avaible of those publications marked with an asterisk. Reprints of other publications may be obtained on application to the Natuurkundig Laboratorium, N.V. Philips' Gleoilampenfabrieken, Eindhoven (Holland), Kastanjelaan.

1432: J. H. de Boer, H. C. Hamaker and E. J. W. Verwey: Electro-deposition of a thin layer of powdered substances (Rec. trav. chim. Pays Bas **58**, 662-665, June 1939).

A simple method is described of depositing thin, uniform, adhering layers of great density of powdered substances on metallic or electrically conducting underlayers. The substance is deposited electrophoretically and the method is based on:

1) the use of suspensions of the substance which has been finely divided by mechanical means, instead of colloidal solutions, and on
2) the application of suitable polar organic liquids as media of dispersion.

1433: J. L. Snoek: Mechanical after-effect and chemical constitution (Physica **6**, 591-592, July 1939).

In connection with **1399**, in which it was shown that small amounts of carbon and nitrogen can cause pure iron to have a strong magnetic after-effect, an attempt was now made to discover whether a mechanical after-effect connected with the former magnetic one could be ascertained. An iron wire carefully freed from carbon by means of hydrogen was found to exhibit only a slight damping of the torsional oscillations between —50° and +100° C, which damping is moreover independent of the temperature. After taking up 0.02% of nitrogen the damping clearly shows a maximum at +9° C. Upon taking up carbon the torsional damping shows a maximum at +24° C. When an iron wire saturated with nitrogen is heated successively to 58°, 100° and 150° C, part of the nitrogen leaves the solid solution and forms a nitride. The maximum of the damping is very much lowered by this treatment. It is therefore very probable that the damping is entirely determined by the amount of nitrogen or carbon in solid solution.

1434-1435: K. F. Niessen and G. de Vries: Ueber die Empfangsimpedanz einer Empfangsantenne. I. Strahlungswiderstand. II. Reaktanz und Abbildungen (Physica **6**, 601-616 and 617-627, July 1939).

The radiation impedance is discussed of an aerial assumed not under load, with a current distribution which, according to von Korshenewsky, will be established upon the incidence of a flat signal wave whose electrical vector oscillates parallel to the aerial. The current distributions are given for several receiving aerials and for several transmitting aerials fed at the centre; they are due to von Korshenewsky and Labus. The reception resistance as a function of the length of the receiving aerial in wave lengths is worked out in detail.

Under the above-mentioned circumstances the reactance of the receiving aerial is calculated in the second article. Reception resistance and reactance are then expressed as the ratios of the thickness and the length of the receiving aerial to the wave length in question. For a given thickness of wire they are compared with the same quantities for the case of a transmitting aerial fed at the centre.

The reception resistance of the wire is usually greater than the radiation resistance in the case where the same wire is used as in a centre fed transmitting aerial, although the minima and maxima lie at about the same lengths.

1436: J. E. de Graaf: Industrial radiography on the continent of Europe (J. Inst. electr. Eng. **84**, 545-551, May 1939).

A short survey is given of the possibilities of application of the röntgenographic examination of the macrostructure of raw materials and products, on which subject a series of articles has already appeared in this periodical: Philips techn. Rev. **2**, 314, 350, 377, 1937 and **3**, 92, 186, 1938. In addition the X-ray apparatus to be used for this macroscopic material inspection is described. This will be discussed shortly in this periodical.

1437: J. L. H. Jonker: Pentode and tetrode output valves (Wirel. Eng. **16**, 274-286 and 344-349, June and July 1939).

The static and dynamic characteristics of screen grid valves are examined in order to find the conditions which must be satisfied by the static characteristic of such a valve in order to guarantee minimum distortion under all circumstances. In order to accomplish this the secondary emission must be suppressed and the deviations to which trajectories of the electrons are subject in the neighbourhood of the grids must be made as small as possible. The manner is further investigated in which secondary electrons pass between two electrodes, and two methods of suppressing this phenomenon are tested: the introduction of a space charge and of a suppressor grid. The best result was obtained by the combination of the two methods and the suppressor grid was found to be the more effective of the two. By careful design of shape and position of the electrodes provision can be made that the electron trajectories have only slight deviations.